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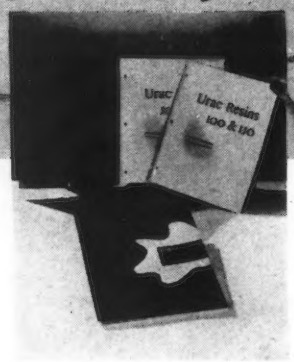

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Modification of Wood and Plywood to Improve Paintability[1]

By

F. L. BROWNE, Chemist
and
D. F. LAUGHNAN, Technologist

Forest Products Laboratory,[2] Forest Service
U. S. Department of Agriculture

INTRODUCTION

The performance of paint on ordinary lumber and plywood has been studied in detail at the Forest Products Laboratory since 1924. Most of the studies concerned house paints because they usually wear out within a few years. Interior coatings may last for many years unless, like floors, they are subject to severe mechanical wear. Interior and exterior coatings are affected by wood characteristics in much the same way except that more concern may be expressed about surface imperfections, such as raised grain and wood checks, in connection with interior than with exterior finishes.

Results of the studies of house paints on ordinary lumber of all of the commercially important native woods have been published repeatedly (9, 11, 13, 14, 15).[3] Plywood has essentially the same painting properties as lumber of the kind of wood with which the plywood is faced. Some plywood is reputed to be more seriously given to face checking than is lumber of the same kind of wood, but, in part, that reputation may be due to the fact that wood checks are more displeasing on the large surfaces presented by plywood than they are on relatively narrow boards.

Although all commercially important softwoods can be kept well painted, some of them are much more exacting than others in their requirements of priming procedures, paints, and maintenance programs. Only 10 percent of the annual cut of softwoods is of the lightweight species easiest to keep well painted, and nearly 70 percent is of the heavy species that require greatest care. Moreover, only a fraction of the production of softwoods is of the clear grades suitable for fully satisfactory painting.

Many studies have been made to find better ways of painting the more exacting woods. Special priming paints were discovered that go a long way toward making the heavier softwoods hold paint as well as the lightweight woods do (3, 6, 7, 12, 17).

As far back as 1929, at a wood-painting conference at the Forest Products Laboratory, representatives of the paint industry suggested that modification of the wood should be considered in an effort to improve paint performance on the more exacting woods; they considered it unfair to hold paint responsible for making all of the modifications needed. Wood surfaces, however, are much less amenable than paint to practicable modifications. As it turned out, some of the most fruitful alterations of wood surfaces had to await the development of new auxiliary materials.

TREATMENT OF WOOD SURFACES WITH CHEMICALS

The studies of paint performance on different woods gave evidence that extractives in some of the woods that are easiest to keep painted, particularly in redwood and southern cypress, exert a favorable effect on the durability of paint (14). Accordingly, tests were started in 1930 in which the aqueous extract of redwood heartwood and the alcoholic extract of cypress heartwood were transferred to the surfaces of boards of eastern hemlock, which were then tested for painting properties. The treated boards gave better paint performance than matched but untreated boards (9). The extent of

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[1] Presented at meeting of the Forest Products Research Society, Pacific Northwest Section, at Portland, Oreg., May 20, 1952.

[2] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

[3] Numbers in parentheses refer to literature cited at end of article.

the improvement, however, was relatively small. The beneficial ingredients in the cypress and redwood extracts are probably antioxidants for linseed oil; in moderate proportions they may retard the embrittlement of paint as it ages. But antioxidants cannot be used in larger proportions for fear of preventing the initial drying of paint. Even the proportions normally present in redwood and cypress seriously retard the drying of many paints under the unfavorable conditions of high humidity, low temperature, and absence of sunlight (2).

In 1932 tests were started in which lumber was treated superficially with reactive gases or with aqueous solutions of inorganic chemicals that alter the pH and might alter the surface reactivity of cellulose and lignin. It was admittedly "shotgun" research without much clear scientific guidance. The hope was that one or more of the treatments might improve the adhesion and durability of paint. None of the treatments, however, improved paint performance; most of them had little or no effect and some impaired paint durability. Perhaps the outcome should have been expected from an understanding of the nature of adhesion of paint to wood (5), for any effect of chemically altering the cellulose and lignin in wood surfaces would have to do primarily with specific adhesion of paint to wood, which is believed to be very good as long as the paint is young but to be gradually lost as the paint becomes embrittled with age (8). Adherence of old paint is thought to be strictly mechanical. If so, the modifications of wood surfaces necessary to improve mechanical adhesion would have to be on a macroscopic or a microscopic scale rather than on a molecular scale. Later in this paper it will be shown that mechanical adhesion of aged paint to the heavier softwoods can be improved by suitable coarse roughening of the surfaces.

DIMENSIONALLY STABILIZED WOOD

Since old, brittle paint adheres to wood mechanically, it is reasonable to suppose that actual breaking away of the coating is hastened by alternate swelling and shrinking of the wood fibers at the interface in response to changes in moisture content. Paint durability, then, should be improved by treating the wood in such a way as to render it more nearly stable, dimensionally; that is, by antishrink treatment, provided that the treatment is not harmful to paint in some other respect. Several methods of stabilizing wood have been developed (19), though none of them is as yet inexpensive and convenient enough to have attained widespread use.

Acetylated Wood

Acetylated wood (20), in which hydroxyl groups of the lignin and cellulose have been esterified with acetic anhydride to the extent of approximately 20 percent by weight, has only 30 percent of the shrinkage of normal wood. Accordingly, preliminary tests were started in 1947 to determine the effect of acetylation on paint performance.

Test panels were 12 by 16 inches in size, made of five-ply, resin-bonded plywood with core and crossbands of Douglas-fir and 1/32-inch face veneers of sweetgum. Panels were made in pairs in which the face veneers of one panel were acetylated and those of the other panel were left untreated for comparison. Twelve pairs of panels were faced with sapwood of sweetgum and four pairs with heartwood of sweetgum. The treated sapwood contained 20 percent of acetyl groups, and the treated heartwood 18 percent. One pair of panels with sapwood faces was exposed without any coating.

Table 1 records the paint, enamel, or lacquer coatings tested and the extent to which the performance of each coating proved better on acetylated than on untreated wood. The meaning of the symbols for concisely indicating the composition of the coatings is explained in the appendix to this report. All coatings of paint or enamel consisted of one application of priming paint or of enamel undercoater followed by two applications of finish paint or enamel. Lacquers were applied by spraying until satisfactory hiding was obtained. The test panels were exposed to the weather in the vertical position, facing south, at Madison, Wis., in March 1947 and were last inspected in September 1951, about 4-1/2 years later.

On 2 pairs of panels out of the 15 pairs no difference in performance of the coatings had appeared up to the last inspection, and the coatings remained in good condition on both treated and untreated wood. On the other 13 pairs of coated panels the performance of the coating proved better on the acetylated than on the untreated wood. Sometimes, as with paint L and with enamel T_{139}(pre), the improvement from acetylation was slight, though it may become more marked as the exposures continue to ultimate coating failure. But with other coatings, such as enamel $(TZ_{15})_{325}$(ar) and with the lacquers, performance was very much superior on the acetylated than on the untreated wood. First evidence of such superiority sometimes appeared as early as November 1948, after 1-1/2 years of exposure. Figure 1 shows some of the results.

Acetylation affected the performance of coatings only in matters of coating integrity, such as cracking, curling, flaking, and scaling. Matters of coating appearance, such as gloss, color, collection of dirt, and susceptibility to mildew, were not affected by acetylation, nor were chalking and erosion as far as could be determined. The pair of panels exposed without any coating proved that acetylation markedly delayed and reduced wood checking and greatly retarded the graying of the wood from weathering. Acetylation, therefore, offers great promise of improving paint performance and minimizing wood checking. A need for further experiments with such woods as Douglas-fir and southern yellow pine, both as plywood and as lumber, is clearly indicated.

Impreg

Another method of improving the dimensional stability of wood is that of impregnation with resin-forming materials followed by curing of the resins in place in the wood structure. The product is known as impreg (18). Preliminary exposure tests of the painting of impreg were started in 1937 and were continued until December 1944.

The test panels were 3/8 by 18 by 18 inches in size, made of three plies of 1/8-inch Douglas-fir veneer. Six panels were made with untreated face plies and six with face plies of impreg produced from the Douglas-fir veneer. All of the panels were bonded with hot-pressed phenolic-resin glue. Before painting, the bottom half (9 by 18 inches) of each impreg-faced panel was thoroughly sandpapered to remove any continuous layer of resin and to permit contact of the paint with impregnated wood fibers. One plain- and one impreg-faced panel were coated on all surfaces and edges with one of each of the following finishes:

1. Three coats of paint L p/nv 0.27.
2. One coat of aluminum house paint plus 2 coats of paint L p/nv 0.27.
3. Three coats of paint $(TL_{28}Z_{28})_{116}$ p/nv 0.29.
4. One coat of aluminum house paint plus 2 coats of paint $(TL_{28}Z_{28})_{116}$ p/nv 0.29.
5. One coat of paint L, plus 1 coat of a mixture of equal parts of paint L and enamel $(TZ_{66})_{207}$(e) p/nv 0.19, plus 1 coat of enamel $(TZ_{66})_{207}$(e) p/nv 0.19.
6. One coat of aluminum house paint, plus 1 coat of the mixture of paint L and enamel $(TZ_{66})_{206}$(e), plus 1 coat of enamel (TZ66)207(e) p/nv 0.19.

The painted panels were exposed to the weather in the vertical position facing south.

There were both favorable and unfavorable developments in paint performance on the impreg as compared with plain Douglas-fir. There was little or no crumbling or flaking of paint from the bands of summerwood in impreg even after 7-1/2 years of exposure. On untreated Douglas-fir, paint L, when self-primed, began to crumble from summerwood after 3-1/2 years and left the summerwood almost entirely bare within 7-1/2 years. Paint $(TL_{28}Z_{28})_{116}$, when self-primed, and enamel $(TZ_{66})_{207}$(e), when primed with paint L, began to flake from the summerwood of untreated Douglas-fir during the fourth and fifth years. But on impreg, paint L showed little crumbling and paint $(TL_{28}Z_{28})_{116}$ and enamel $(TZ_{66})_{207}$(e) showed no flaking over summerwood after 7-1/2 years. Use of aluminum primer on plain Douglas-fir also succeeded in preventing crumbling or flaking from summerwood, though no more effectively than the impreg did.

Both of the paints and the enamel, however, developed their normal checking or cracking patterns just as early over impreg as they did on plain Douglas-fir. But on impreg the checking or cracking led to alligatoring during the fourth year with the enamel or the fifth year with the two paints. With paint L the alligatoring was confined to the summerwood bands in the impreg. Alligatoring occurred earlier and became much more pronounced when paint $(TL_{28}Z_{28})_{116}$ or the enamel were applied over aluminum primer on the impreg than when they were applied over white primer. Thus the beneficial effect of impreg in preventing crumbling and flaking was partly offset by a tendency to cause alligatoring. It is possible, however, that the finishing systems were more than usually prone to alligatoring in consequence of their application indoors without exposure to sunshine between coats, for paint $(TL_{28}Z_{28})_{116}$ eventually became distinctly alligatored over aluminum primer on untreated Douglas-fir. Nevertheless, the alligatoring in the 1937 tests on impreg should be kept in mind in connection with the alligatoring reported later on in the 1941 tests on plywood covered with resin-impregnated paper pulp.

Sandpapering the surfaces before painting exerted little or no effect on the performance of the coatings. On two or three of the panels there was slightly less alligatoring over the sandpapered than over the unroughened part of the surface, but the difference was too slight to be considered significant.

No wood checking ever appeared in the impreg-faced panels. The plain Douglas-fir faces, however, developed a moderate degree of wood checking during the course of the tests.

Figure 2 shows how the impreg prevented crumbling and flaking from summerwood. It also shows alligatoring over the impreg not found on the comparison panels of plain Douglas-fir.

PAPER COVERING

In 1932, following a proposal by M. E. Dunlap of the Forest Products Laboratory, tests were started in which 6-inch bevel siding of southern yellow pine was covered on all six sides with paper. To make the test panels, 6-foot boards were cut in half (to 3-foot lengths) and paper glued to one half but not to the other half. Thus panels of covered and of ordinary siding were assembled in which the wood was carefully matched. Two weights of paper were tested, one a thin, unsized tissue paper and the other a fairly heavy kraft wrapping paper. The paper was glued in place with water-resistant animal glue of the paraformaldehyde formula (1), inasmuch as resin glues had not yet been developed.

A covered and an uncovered test panel were painted with three coats of paint L p/nv 0.27, and another pair of panels was painted with paint $(TZ_{23})_{92}$ p/nv 0.29. During the painting the panels were exposed to sunshine for 8 hours between coats of paint. After painting the panels were exposed at 45 degrees from the vertical facing south on the test fences at Madison, Wis. The exposures lasted from August 29, 1932 to July 8, 1935.

The results are summarized in Table 2. Paint was applied slightly more generously over paper of each kind, making slightly thicker coatings, than over uncovered wood. The coatings were somewhat thicker than 0.005 inch, generally considered optimum for initial paint jobs on previously unpainted wood. As a result the coatings were distinctly more durable than is normally expected on southern yellow pine exposed at 45 degrees facing south, but when flaking or scaling began the stresses operating at the paint-paper interfaces may have been abnormally high.

Figure 3 shows the panels painted with pure white lead paint at the conclusion of the tests. The covering of kraft paper succeeded in preventing early crumbling from the summerwood, which can be plainly seen on the uncovered panel, and thereby materially prolonged the durability of the coating. Similar results were obtained with paint $(TZ_{23})_{92}$. The tissue paper, however, proved too weak to withstand the shrinking of crumbling or scaling paint after it has checked or cracked and started to break away. The kraft paper, moreover, kept the exposed surfaces free from observable wood checking and reduced the amount of cupping of the boards under the severe weathering conditions of the test.

The test panels were removed from the fence in 1935 and stored in a laboratory, kept warm but not humidified in winter, until April 1937. Drying of the wood led to shrinkage, which partly loosened the glue bond between kraft paper and wood and left the paper slightly rumpled. The panels covered with kraft paper and their matched but uncovered panels were then repainted with two coats of fresh paint of the kinds used originally and were restored to the test fences, but this time in the vertical position facing south. The new exposures continued until the summer of 1944. Re-absorption of moisture out of doors soon swelled the wood sufficiently to draw the kraft paper taut again, but contraction of the paint coating as it aged cracked the paper over the areas where the glue bond had broken. Paper and coating then began to curl and scale from the wood. On the other hand, where the paper remained firmly glued to the wood, it continued to improve paint durability by preventing crumbling or flaking from the summerwood bands.

The 1932 tests showed clearly that a covering of paper of sufficient strength would greatly improve the performance of paint on the heavy softwoods provided that the paper could be held firmly in place by more weather-resistant glue than animal glue treated with paraformaldehyde.

Tests in 1949

In 1949 further studies were made with paper coverings on southern yellow pine. Paper was glued to both faces of boards 25/32 inch thick and 6-1/4 inches wide.[4] The boards were then resawed and edge-jointed to make nominal 6-inch bevel siding with paper glued on the exposed faces only. Preliminary tests showed that ordinary paper gave trouble in jointing or cross-cutting because the paper became badly frayed at the edges. Kraft paper impregnated with 5 percent by weight of water-soluble phenolic resin and cured without pressure at 325° F. for 15 minutes, when glued to the boards permitted cutting to smooth edges without any fraying.

[4] Bruce G. Heebink designed and prepared all of the paper-covered boards for these tests.

For the tests two thicknesses of treated kraft paper were used on different panels, namely, 2 mils and 6 mils. For each thickness of paper, test panels were made with each of three different glues to bond the paper to the wood, namely, casein glue, urea-resin glue, and a phenolic-resin glue of the type curing at room temperature. For each combination of thickness of paper and kind of glue, one test panel was exposed on the test fences without painting and one panel was painted on the exposed face. There were also two panels of southern yellow pine without covering of paper, one painted and one allowed to weather without painting. All painting consisted of a priming coat of paint $(TL_{25})_{79}$ p/nv 0.35 and one finish coat of paint $(TZ_{20}Z_{20})_{114}$ p/nv 0.30, which made coatings approximately 3.4 mils thick. The panels were exposed vertically, facing south, from July 27, 1949 to October 31, 1950.

Within 2 or 3 weeks after starting the exposures, some of the panels covered with casein-glued paper, both painted and unpainted, began to show blisters where there was separation at the wood-paper interface. There was also some separation of paper from wood along the bottom edges of boards. Such early failures are attributed to inadequate gluing; probably to unduly long assembly time in the gluing operation. By October 1950, after 14-1/2 months, all unpainted panels with paper covering blistered and loosened at bottom edges; those with casein glue were most seriously and those with phenolic-resin glue least seriously damaged. The painted panels with paper covering glued with either urea-resin or phenolic-resin glue were still in excellent condition.

The painted panels with paper glued with urea-resin or phenolic-resin glue and the painted panel without paper were reassembled and restored to the test fence in the spring of 1951. By May 1952, after a little more than 2 years of total exposure, there was blistering on all of the paper-covered panels. On the control panel without paper the paint was beginning to flake from summerwood. On paper coverings there was no paint flaking. The 2-mil paper did not succeed in hiding raised grain, but the 6-mil paper allowed no raised grain to show.

Paper covering for the exposed faces of siding, if about 6 mils thick, shows promise of improving paint performance on the heavier softwoods, but more work is needed to develop the technique of gluing the paper in place reliably.

COVERINGS OF RESIN-IMPREGNATED PULP OR PAPER

In 1941 tests were started with a commercial product consisting of exterior-grade plywood of Douglas-fir faced on both sides with a covering said to be pulpboard impregnated and glued to the plywood with phenolic resin. The pulpboard may have been somewhat compressed in the hot-press gluing, but it was by no means saturated with resin and remained somewhat porous, though not so absorptive of liquids as wood is. The covering was 1/32 inch thick.

Test panels were 2 feet by 6 feet in size but were marked off into test areas 2 feet by 1-1/2 feet in size. Panels were mounted in the vertical position on both the north side and the south side of the test fence so that the backs, which remained unpainted, were not exposed to the weather. The upper half of the exposed face of each panel was sandpapered enough to roughen the surface slightly and to remove any continuous film of resin that might have been at the surface. On any one panel each test area received a different priming coat or combination of priming coat and undercoat, but all four test areas of any one panel received the same finishing paint or enamel. During painting the panels were exposed to sunshine for at least 8 hours between coats. The panels were exposed on the test fence at Madison, Wis., on June 3, 1941, and the final inspection was made on August 25, 1944.

It was found that priming paints spread about 15 to 20 percent farther on the surfaces of resin-impregnated pulpboard than they did on wood. The difference arose from less absorption of paint liquids by the impregnated surfaces. The thickness of dried coating formed was probably about the same as on wood.

Sandpapering the surfaces before painting usually exerted no effect on the performance of the coating, but with 8 of the 24 coating systems tested the durability was impaired, sometimes seriously, by sandpapering.

Table 3 lists the coating systems tested and the important observations of their performance. Unpigmented primers such as wood sealer and spar varnish had markedly adverse effect on the durability of the paints and enamels. Aluminum house paint as a primer gave the best performance with the two house paints and one of the enamels, and one of the best with the second enamel. The presence of any zinc oxide in a primer proved distinctly harmful to the durability of any of the paints or enamels

applied over it. Figures 4 and 5 show some of the results. The most significant development in the tests, however, was the tendency for many of the coatings to become alligatored, sometimes seriously so. With all of the coatings tested, alligatoring must be considered an abnormality of performance. Yet only three of the systems (both of the enamels when applied over aluminum primer and enamel T_{420}(ar) when self-primed) remained entirely free from alligatoring. Presence of zinc oxide in a primer under either of the house paints made alligatoring especially conspicuous. Sandpapering before painting either failed to alter or increased the tendency toward alligatoring.

Since the abnormality of alligatoring had appeared previously in resin-impregnated surfaces in the 1937 tests of impreg, there seemed to be a strong presumption that the impregnating resin was responsible for it. Incompatibility between the resin and paint coatings seemed to be indicated. The findings that the antagonism was worse toward house paints, with oil vehicles, than toward enamels, with resinous vehicles, and that presence of zinc oxide in a primer was an aggravation, were consistent with that view. Nevertheless, judgment should be reserved in the light of tests described farther on.

Although no further tests have been made at the Forest Products Laboratory with the resin-impregnated pulpboard surfacing, one of the authors (F. L. Browne) has seen adequate tests made by a paint manufacturer' s laboratory in the Chicago area with the same brand of covered plywood as manufactured since the close of the war. Paint and enamel systems reasonably similar to those of the Forest Products Laboratory tests were used. No difficulty with alligatoring was experienced in the more recent tests. It is not known whether the covered plywood had been changed in any way, such as by the amount or kind of resin used, by the curing conditions, or by any lubricants used on the press cauls.

Papreg Tests

A wartime study of problems in aircraft finishing, started in 1943, involved comparative tests of 44 different finishing systems on birch plywood, poplar plywood, and on papreg, which is a resin-impregnated paper laminate containing about 35 percent of phenolic resin (16) and compressed to a smooth surface that is practically nonabsorptive of paint liquids. Before applying finishes, half the area of each test panel of papreg was sandpapered enough to destroy the glossiness and to make the surface slightly rough.

The finishes applied were all commercial products, most of which presumably conformed to currently applicable military specifications of the performance type, but the composition of the finishes was only partly disclosed. They included oleoresinous enamel systems, nitrocellulose lacquer systems, and nitrocellulose dope systems with and without fabric. In each class there were sealers, surfacers, and pigmented finish coats that were tested in several combinations. Both glossy and lusterless (camouflage) finish coats in yellow, dark-blue, aluminum, and olive-drab colors were included. There were no house paints.

The outcome of the tests failed to indicate any incompatibility between papreg and the finishes of aircraft type. Abnormal forms of failure such as alligatoring or coarse scaling were almost entirely absent. In general, the the ultimate form of failure of each coating was essentially the same on papreg and on plywood, though the rate at which failure took place varied among the substrates.

As a rule, the finishes lasted longer on papreg than on yellow-poplar plywood and longer on yellow-poplar than on birch plywood. According to a scoring system adopted for the purpose in which the highest number represented the longest life of the coating, the average score for all finishes on papreg was 4.7, on yellow-poplar 3.6, and on birch 3.0. Oleoresinous finishes outlasted lacquer finishes, but the difference between them was much less on papreg than on plywood. Thus the scores for oleoresinous finishes on papreg and on yellow-poplar were 4.8 and 4.3, respectively, whereas for lacquer finishes the corresponding scores were 4.0 and 2.5. Sandpapering the surface of papreg had little effect on the performance of finishes. For 34 finishing systems there was no observable effect of sandpapering, for 5 systems durability was slightly impaired, and for 5 it was slightly improved by sandpapering.

Resin-Impregnated Paper Covering (1944)

A comprehensive series of tests was started in 1944 on Douglas-fir plywood with and without covering on both faces with resin-impregnated paper. The covering consisted of three plies of paper containing 40 to 50 percent of water-soluble phenolic resin, subsequently cured and compressed to a thickness of 0.009 inch, and having a weight of 80 pounds per thousand square feet of single surface. The press cauls used produced a surface of very low gloss and a slight degree of roughness. The covering material used was a commercial product, the manufacturer of which supplied both the covered and uncovered plywood for the tests.

The size and arrangement of test panels on the test fence at Madison, Wis., were essentially the same as has already been described for the 1941 tests of resin-impregnated pulpboard covering, except for a much greater number of panels and for repetition of all tests on plain plywood as well as on the covered plywood. There were 320 test areas, 160 of which were plain plywood and 160 were plywood covered with resin-impregnated paper. Eighty test areas of each kind were exposed facing south and 80 facing north. A total of 77 finishing systems were tested, of which 33 were house-paint primers and house paints, 36 were oleoresinous enamels with various primers and undercoaters, and 8 were nitrocellulose lacquer systems. For the present purpose it is sufficient to report results with 18 of the house-paint systems and 10 of the enamel systems in table 4. With respect to the nature of the differences in performance on plain and covered plywood, the unreported finishing systems behaved like those reported.

The upper halves of all test areas of plywood covered with resin-impregnated paper were sandpapered before any finishing material was applied. As a rule, such roughening of the surface produced no noticeable difference in the performance of the coatings on exposure. On 6 of the 80 test areas of covered plywood facing south the coating failed slightly more rapidly on the sandpapered portion than it did on the unroughened portion. All of the tests of resin-impregnated surfaces, whether wood, pulpboard, or paper, indicate that sandpapering seldom proves helpful, usually has little effect, and when it does is more often harmful than beneficial.

The upper halves of all test areas of plain plywood in the 1944 tests were treated with a water repellent before painting. The water repellent was a solvent naphtha solution of 1.5 percent of paraffin wax and 13.5 percent of resin by weight. The treatment failed to improve the performance of any of the finishing systems tested. It likewise failed to effect any noticeable reduction in the amount of face checking of the plywood during the course of the tests.

During the painting it was found that the first coat of finishing material applied, whatever its nature, usually was spread farther on the nonabsorptive surface of the covered plywood than it was on plain plywood. The average spreading rate for all first coats was 900 square feet per gallon on covered and 600 square feet per gallon on plain plywood. Thus the covered plywood requires only two-thirds the material needed for plain plywood. When the thicknesses of dried coating were calculated, assuming no absorption of primer liquids by the resin-impregnated paper, the average for all first coats was 1.1 mils for both the plain and covered plywood. The difference in consumption of priming material, then, seems to be wholly the quantity absorbed by plain wood.

The average spreading rates for all second coats were 611 and 653 square feet per gallon on plain and on covered plywood, respectively. The corresponding averages for all third coats were 722 and 713. Thus in applying coatings about 4.5 mils thick, there was a saving of a little less than 15 percent of finishing material for the covered plywood as compared with plain plywood.

The covering of resin-impregnated paper presented a smooth, uniform surface on which enamel finishes appeared to best advantage; on plain plywood the appearance of the enamels was often impaired by slightly raised grain in the wood, which formed noticeable ridges in the enamel surface over some of the bands of summerwood. With paint finishes such effects of slightly raised grain were usually made inconspicuous by the pattern of brush marks left in the surface of the coating.

Table 4 shows that nearly all coatings proved more durable on the covered than on the plain plywood. Only the southern exposures are reported because in 6 years the coatings facing north did not deteriorate sufficiently to estimate their relative durabilities. The advantage for the covered plywood was usually greatest for the least durable coatings. Thus the systems consisting of sealer followed by two coats of house paint lasted about 20 months longer on covered than on plain plywood. Where coatings were durable for 70 months or longer on plain plywood, the durability on covered plywood could hardly be more than a few months longer. The average durability of 33 house-paint systems was 58 months on plain plywood and 74 months on covered plywood. For 36 enamel systems the average durability was 63 months on plain and 77 months on covered plywood. For 8 lacquer systems the average durability was 51 months on plain and 71 months on covered plywood.

Particularly significant is the fact that the difference between the most durable and the least durable coating on covered plywood was much less than the corresponding difference on plain plywood. In other words, the covered plywood proved materially less sensitive to variation in the quality of the coating than was plain plywood. A few of the most durable

finishing systems on plain plywood, particularly those in which aluminum priming paint was used, compared favorably in durability with the best systems on covered plywood.

The optimum pigment volume for priming coats in house-paint systems turned out to be somewhat higher for covered plywood than for plain plywood. On covered plywood pigment volume 0.4 generally gave best results, but on plain plywood 0.3 or sometimes even 0.2 proved better. Such difference was to be expected because wood absorbs much of the liquid from priming coats and thereby raises the pigment volume in the dried coating, whereas on resin-impregnated paper there is no such absorption. For enamel systems special primers or undercoaters usually proved advantageous for plain plywood, but on the covered plywood the simpler practice of priming with the same enamel used for the finish coat often proved better.

Figure 6 shows how coating on plain plywood eventually wore out by crumbling or flaking from summerwood until the grain pattern of the wood was clearly revealed. On covered plywood, shown in Figure 7, crumbling or flaking set in irregularly, following no pattern related to the grain of the wood or the structure of the covering. In general, each paint or enamel followed its own characteristic course of disintegration by checking and crumbling or by cracking, curling, and flaking, whether it was on plain plywood or on covered plywood. The covering, however, succeeded in preventing the unduly early onset of crumbling or of flaking from summerwood that is so troublesome on the heavier softwoods.

In the 1944 tests on resin-impregnated paper coverings none of the paints, enamels, or lacquers tested developed abnormal alligatoring such as was observed in the 1937 tests on impreg and the 1941 tests on resin-impregnated pulpboard coverings. This was true even though a number of the priming paints or enamel undercoaters contained zinc oxide. The alligatoring of coatings in the 1937 and 1941 tests, therefore, cannot be attributed to the mere presence of resin in the surface or of zinc oxide in the priming coat. The alligatoring that has been observed in certain tests remains for the present unexplained. Until more is learned about it, resin-impregnated surfaces must be tested for paint performance on them to see whether difficulties with alligatoring may be experienced. The Forest Products Laboratory has more recent tests underway on paper coverings impregnated with varying proportions of different resins, but the work has not yet advanced sufficiently to warrant detailed description.

Resin-Bonded Sawdust Covering

Tests were started in 1951 on a commercial product that consists of Douglas-fir plywood covered on one face only with a finely granular material said to be finely ground wood waste bonded together and to the plywood with resin. The surface presented is light in color, lusterless, and slightly rough to feel. It was found to be much more absorptive of paint liquids than plain plywood.

When oil-rich house paints were thinned with extra linseed oil or paint thinner for application on the covered plywood, the granular covering absorbed liquid so rapidly and extensively that the paint became dry under the brush and was exceedingly difficult to spread evenly. Brushing had to be done very quickly. Excessive quantities of priming paint were consumed, up to half again as much as was needed for plain plywood. Moreover, such primers failed to seal the surface adequately to permit one subsequent coat of finish paint to dry with uniform gloss. A second finish coat, the third coat in all, dried with uniform gloss.

Special house-paint primers made with a substantial proportion of bodied oil, which provides the property commonly called controlled penetration, proved reasonably satisfactory on the granular covering, though it was still necessary to spread the paint rapidly. The extra consumption of special priming paint was only 3 to 15 percent of that needed on plain plywood. One coat of house-paint primer sealed the surface well enough for one coat of finish paint to dry with uniform gloss.

Covering the plywood on one face only produced an unbalanced construction that led to marked cupping of the test panels while they were in process in the carpenter shop and painting laboratory. The covered face became concave. When the panels were straightened by nailing them in place on the test fence, a number of conspicuous cracks developed in the granular covering and the coating of paint over it. It would be advisable to balance the construction of the product to avoid such difficulties, because precise control of moisture content at all times during building construction cannot be expected.

The tests have not yet been exposed long enough to give significant indication of the performance of the coatings.

MECHANICAL TREATMENT OF WOOD SURFACES

The chief shortcoming of the heavier softwoods comes from the wide bands of summerwood presented for contact with the paint coating.

Edge-grain boards, in which the bands of summerwood are of minimum width, hold paint materially longer than otherwise similar flat-grain boards. Better paintability of flat-grain boards should be expected if a mechanical processing of the surfaces can be devised to subdivide the wide bands of summerwood.

Douglas-fir plywood with striated surfaces, such as are shown in Figure 7, has been on the market for some time. From observations of practical experience like that shown in Figure 8, it is evident that the striations succeed in improving paint performance by narrowing the bands of summerwood in contact with the paint. In addition, the process very significantly reduces face checking in Douglas-fir plywood.

In 1951 the Forest Products Laboratory began tests of striations on lumber siding of Douglas-fir and of southern yellow pine. The tests are not yet old enough to tell whether an improvement in paint performance has been effected. They have shown, however, that when siding is erected with the striations horizontal, the paints often become more seriously soiled with dirt than they do on smooth lumber or on striated lumber erected vertically. Further tests would be highly desirable in which other patterns of striations would be tried, particularly if some mechanical method of narrowing the bands of summerwood without so greatly altering the appearance of the painted wood could be found.

CONCLUSION

The heavier softwoods, which are the most abundantly available woods for building construction, are less desirable for durable painting than the lightweight but less abundant softwoods. Paint performance on the heavier softwoods can be improved by careful selection, application, and maintenance of the most suitable paints, but it can also be improved with a wider tolerance for different kinds of paints by any one of several methods of specially processing lumber or plywood.

The beneficial processing methods discovered thus far depend on more than one principle, stabilizing the wood against swelling and shrinking, covering the wood with thin layers of uniformly textured material, and mechanically treating the surface to subdivide the troublesome wide bands of summerwood.

Moisture stability can be imparted by acetylating the wood, or at least the parts of the wood nearest the painted surface. The method involves problems of chemical engineering that have not yet been completely solved, but it offers promise of better paint performance without appreciable change in any of the desirable properties of wood. Stabilization by suitable impregnation with resins is also effective in improving paint performance, but it alters the weight, appearance and toughness of wood and adds seriously to cost.

Coverings to improve paintability have so far been developed more extensively for plywood than for lumber, though in principle they are applicable to both. Successful coverings usually involve resin impregnation, which under some circumstances not yet fully understood may tend to cause abnormal alligatoring of coatings, though it is evident that such troubles can be controlled when more is known about them. Coverings can be made of pulpboard, paper, ground wood, and doubtless of other materials not yet tried. Coverings materially alter the appearance of wood for use without finishes or with transparent finishes.

Mechanically striating the surfaces of Douglas-fir plywood greatly improves paint performance and minimizes face checking. The process should be applicable to other woods, including lumber. The striations now used greatly alter the appearance of wood, though the novel appearance is an advantage for many purposes. Other methods of mechanical treatment that produce less alteration of appearance might well be sought.

How far the burden of changing customary practices in the interest of better paint performance should fall on lumber producers and how far on paint makers is a matter for the give and take of industry to determine. It has now become evident that, from at least the technical point of view, progress can be made on both sides of the paint-wood interface.

APPENDIX

The method used to express the approximate composition of house paints concisely by suitable symbols was published in 1937 (10). Capital letters with their subscripts stand for the opaque white pigments and their proportions in percentages of the total pigment by volume. The letter L stands for white lead, Z for zinc oxide, T for titanium dioxide, and S for zinc sulfide. Thus paint L was pure white-lead paint. It might be written L_{100}, but the subscript is omitted when it is obvious. Paint LZ_{55} would have a pigment composed of 55 percent zinc oxide and 45 percent (100 minus 55) by volume of white lead. In a paint

$(LZ_{30})_{80}$, the parentheses indicate that the opaque pigments, white lead and zinc oxide, together amounted to 80 percent of the total pigment (30 percent of zinc oxide plus 50 percent white lead). The remaining 20 percent of pigment in this paint would be extending pigments. When titanium dioxide is present, it is assumed that, unless otherwise indicated, there are 3.2 volumes of extending pigment for each volume of titanium dioxide. Thus, paint $TL_{28}Z_{28}$ was paint with a pigment composed of 28 percent zinc oxide, 28 percent of white lead, and 44 percent of titanium pigment (100 less 28 for the zinc oxide, less 28 for the white lead), or 10.5 percent of titanium dioxide (44 divided by the quantity (3.2 plus 1)) and 33.5 percent of extending pigment. But in paint $(TL_{28}Z_{28})_{116}$ the equivalent opaque pigment was 116 percent, signifying less than the standard dilution of titanium dioxide with extending pigment; hence, the content of titanium dioxide was 14.3 percent (116 minus 28 minus 28 divided by the quantity (3.2 plus 1)) and that of extending pigment was 29.7 percent (100 minus 28 minus 28 minus 14.3).

Unless otherwise indicated, the nonvolatile vehicle in house paints is understood to be a drying oil, such as linseed oil, chiefly in unbodied (not thickened in viscosity) form. In priming paint TL_{29}(e) or in enamel $(TL_{10}Z_{20})_{123}$(e) much or all of the drying oil was bodied. In an enamel $(TZ_{25})_{138}$(re) the vehicle would contain resin of unspecified kind and bodied oil, that is, an oleoresinous varnish. In enamel $(TZ_{25})_{138}$(pre) the varnish was one made with phenolic resin. In enamel T_{246}(ar) the vehicle was an alkyd resin with no bodied drying oil other than that contained in the resin itself. If bodied drying oil were added together with the alkyd resin, the symbol would be (are).

The ratio by volume of total pigment to total nonvolatile material in a paint, which is also the fraction of the dried coating occupied by pigment, is indicated by the symbol p/nv and the appropriate decimal fraction. Thus p/nv 0.29 means that the paint, as used for the finish coat, contained 0.29 gallon of total pigment to a gallon of total nonvolatile material.

LITERATURE CITED

1. Browne, F. L. and Hrubesky, C. E. 1927 Water-resistant animal glue. Ind. Eng. Chem. 19:215.

2. Browne, F. L. 1930 Drying of exterior paints under various conditions and over different woods. Ind. Eng. Chem. 22:400.

3. _____ 1930 Effect of priming-coat reduction and special primers upon paint service on different woods. Ind. Eng. Chem. 22:847.

4. _____ 1930 Procedure used by the Forest Products Laboratory for evaluating paint service on wood. Am. Soc. for Testing Materials, Proceedings 30(2):852.

5. _____ 1931 Adhesion in the painting and in the gluing of wood. Ind. Eng. Chem. 23:290.

6. _____ 1934 Effect of aluminum priming paint on the durability of house paints on wood. Ind. Eng. Chem. 26:369.

7. _____ 1935 Special priming paints for wood. Ind. Eng. Chem. 27:292.

8. _____ 1935 Effect of change from linoxyn gel to xerogel on the behavior of paint. Colloid Symposium Monograph 11:211.

9. _____ 1936 Effect of extractive substances in certain woods on the durability of paint coatings. Ind. Eng. Chem. 28:416.

10. _____ 1937 A proposed system of classification for house paints. Ind. Eng. Chem. 29:1018.

11. _____ 1940 Painting and finishing wood, chapter 7 in "Wood Handbook" of the Forest Products Laboratory, unnumbered publication of the U. S. Dept. of Agriculture, Supt. of Documents, Washington, D. C.

12. _____ 1941 The two-coat system of house painting. Ind. Eng. Chem. 33:900.

13. _____ 1937 Wood properties and paint durability. U. S. Dept. of Agriculture, Miscellaneous Publication No. 629, Supt. of Documents, Washington, D. C.

14. _____
1948 Behavior of house paints on different woods, Forest Products Laboratory Report No. R1053.

15. _____ and Rietz, R. C.
1949 Exudation of pitch and oils in wood. Forest Products Laboratory Report No. R1735.

16. Erickson, E. C. O. and Mackin, G. E.
1945 Paper-base laminates offer high strength. Plastics 2(2):26 and Am. Soc. Mech. Eng. Trans. 67(4):267.

17. St. Paul Test Fence Committee
1934 Priming-coat reductions for painting new wood surfaces. Am. Paint J. 19(Dec. 10):7.

18. Stamm, A. J. and Seborg, R. M.
1936 Minimizing wood shrinkage and swelling. Treating with synthetic resin-forming materials. Ind. Eng. Chem. 28:1164.

19. Tarkow, H.
1949 Swelling and shrinking of wood, paper, and cotton textiles and their control. Tech. Assoc. Pulp and Paper Ind. 32:203.

20. Tarkow, H. and Stamm, A. J.
1950 Acetylated wood. Forest Products Laboratory Report No. 1593.

Table 1.--The 1947 tests on acetylated wood -- relative performance of coatings on acetylated as compared with untreated wood after 4-1/2 years' exposure to the weather facing south at Madison, Wis.

Priming paint or enamel undercoating		Finish paint or enamel		Relative performance of coating on acetylated sweetgum as compared with untreated sweetgum
Chief ingredients and their proportions[1]	Pigment volume, p/nv	Chief ingredients and their proportions[1]	Pigment volume, p/nv	
On panels faced with sweetgum sapwood				
L	0.30	L	0.30	Slightly[2] more durable
$TL_{30}(e)$	.40	$(TL_{29}Z_{30})_{168}$	.29	Distinctly more durable
$(TL_{30}Z_{30})_{168}$	.19	$(TL_{29}Z_{30})_{168}$	.29	Distinctly more durable
$T_{133}(e)$	.60	$(TL_{10}Z_{20})_{133}(e)$	.40	Distinctly more durable
$T_{133}(e)$	.60	$T_{133}(e)$	.40	No difference up to 4-1/2 years
$T_{133}(e)$	.60	$T_{139}(pre)$	.31	Very slightly more durable
$T_{133}(e)$	.60	$T_{244}(ar)$	.22	Markedly more durable
Low-viscosity nitrocellulose lacquer enamel, white				Very markedly more durable
High-viscosity nitrocellulose lacquer enamel, white				Markedly more durable
Aluminum[3]	--	$(TL_{29}Z_{30})_{168}$	.29	No difference up to 4-1/2 years
$T_{133}(e)$	.60	$(TZ_{15})_{325}(ar)$	.36	Very markedly more durable
On panels faced with sweetgum heartwood				
L	.30	L	.30	Slightly more durable
$(TL_{30}Z_{30})_{168}$	.19	$(TL_{29}Z_{30})_{168}$	.29	No difference up to 4-1/2 years
$T_{133}(e)$	.60	$T_{244}(ar)$	.22	Distinctly more durable
Low-viscosity nitrocellulose lacquer enamel, white				Very markedly more durable

[1] For the meaning of the symbols for compositions of paints see the appendix to this paper.

[2] The adverbs indicate increasingly significant differences in the following order: very slightly, slightly, distinctly, markedly, very markedly.

[3] Aluminum house paint made with aluminum powder in bodied linseed oil, resin-free vehicle.

Table 2.--The 1932 tests on paper coverings glued on southern yellow pine bevel siding

Covering on siding	Paint coating (Three coats were applied)		Relative performance	
	Kind of paint[1]	Thickness[2]	Durability[3]	Integrity[3] after 35 months
		Mils	Months	
Kraft paper	L p/nv 0.28	6.1	35	Poor[4]
None	do	5.2	29	Bad
Tissue paper	do	6.6	22	Bad[5]
None	do	5.8	30	Bad+
Kraft paper	$(TZ_{23})_{92}$ p/nv 0.28	6.6	35	Poor[4]
None	do	6.0	30	Bad
Tissue paper	do	6.1	25	Bad[5]
None	do	5.9	25	Bad

[1] For the meanings of the symbols for composition of the paints see the appendix to this paper.

[2] Thickness of the dried coating was calculated from the spreading rates by methods previously described (12). One mil is 0.001 inch.

[3] Successive stages in the deterioration in integrity of coatings are rated good, fair, poor, and bad with the added subdivisions of high (+), medium, and low (-) in each stage. The time elapsed until the coating reaches medium poor, when it is considered ready for repainting, is called the durability (4).

[4] Crumbs or flakes of paint became detached from the surface of the kraft paper, leaving the paper firmly attached to the wood.

[5] Crumbs or scales of paint that became detached took with them part or all of the tissue paper, that is, the line of separation was chiefly within the paper.

Table 3.—The 1941 tests on Douglas-fir plywood covered with resin-impregnated pulp board.

Painting system[1]			Thickness of coating[2]	Performance of coating during exposure					
				Facing south			Facing north		
First coat—(p/nv)	Second coat—(p/nv)	Third coat—(p/nv)		Alligatoring[3]	Rating for coating integrity[4] after 39 months	Durability[5]	Alligatoring[3]	Rating for coating integrity[4] after 39 months	Durability[5]
			Mils						
Wood sealer	L (0.37)	L (0.27)	4.0	T	[6]Bad+	18	T	Poor+	42
Spar varnish	do	do	4.2	S	[6]Bad+	18	M	Poor+	42
L (0.37)	do	do	5.1	T	Poor	39	T	Fair-	45
Aluminum[7]	do	do	4.3	S	Poor+	42	O	Fair+	51
$(TL_{58})_{208}(e)(0.20)$	L (0.27)	None	3.9	M	[6]Poor	39	M	Poor	39
$TL_{28}(e)(0.40)$	do	do	4.4	S	Poor+	42	M	Poor+	42
L (0.37)	do	do	4.3	T	Poor	39	T	Fair	48
L (0.23)	do	do	3.9	M	Bad	22	O	Fair	48
Wood sealer	$(TL_{28}Z_{28})_{116}(0.29)$	$(TL_{28}Z_{28})_{116}(0.29)$	4.2	T	[6]Bad+	28	M	Poor	39
Spar varnish	do	do	4.4	V	[6]Bad+	28	M	Poor+	42
$(TL_{28}Z_{28})_{116}(0.40)$	do	do	5.0	VM	[6]Bad	24	VM	Bad	27
Aluminum[7]	do	do	4.5	M	[6]Poor	39	S	Poor+	42
$(TL_{58})_{208}(e)(0.20)$	$(TL_{28}Z_{28})_{116}(0.29)$	None	3.6	T	Poor+	42	S	Fair-	45
$TL_{28}(e)(0.40)$	do	do	4.0	S	Poor+	42	T	Fair-	45
$(TL_{28}Z_{28})_{116}(0.40)$	do	do	3.7	VM	[6]Bad-	15	VM	Bad	27
$(TL_{28}Z_{28})_{116}(0.23)$	do	do	4.5	VM	Bad+	22	VM	Bad+	30
$(TL_{20}Z_{30})_{126}(e)(0.29)$	$(TL_{20}Z_{30})_{126}(e)(0.29)$	$(TL_{20}Z_{30})_{126}(e)(0.29)$	5.6	T	[6]Bad+	28	O	[6]Poor	39
$(TL_{20}Z_{10})_{78}(e)(0.60)$	$(TL_{20}Z_{10})_{78}(e)(0.60)$	do	4.3	T	[6]Bad	25	O	[6]Fair-	45
$TL_{28}(e)(0.40)$	do	do	4.4	T	Poor+	42	O	Good	57
Aluminum[7]	do	do	3.7	O	Fair	48	O	Good	57
$T_{144}(e)$ (0.30)	$T_{144}(e)(0.30)$	$T_{420}(ar)(0.18)$	2.6	S	Poor-	29	T	Fair-	45
$T_{420}(ar)$ (0.18)	$T_{420}(ar)$ (0.18)	do	2.5	O	Fair+	51	O	Good	57
$TL_{28}(e)$ (0.40)	$T_{144}(e)$ (0.30)	do	2.9	VM	Poor-	31	S	Fair-	45
Aluminum[7]	do	do	2.2	O	Fair+	51	O	Good-	54

[1] For meanings of the symbols for composition of paints see the appendix to this paper.

[2] Coating thickness was calculated by the Forest Products Laboratory method (12) except that the resin-impregnated pulpboard is assumed to absorb only one-fourth of the nonvolatile vehicle from priming coats. One mil is 0.001 inch.

[3] Degree of alligatoring indicated by O for none, T for trace, S for slight, M for marked, VM for very marked. Degrees M and VM were conspicuous enough to bring the rating for integrity of coating into poor or bad stage even though there may have been no crumbling or flaking.

[4] Successive stages in the deterioration in integrity of coatings are rated good, fair, poor, and bad with the added subdivision of high (+), medium, and low(-) in each stage (4).

[5] The durability is the age of the coating when it was first rated medium poor in integrity.

[6] Sandpapering the surfaces before painting proved harmful to the durability of the coating. The rating recorded is for the part that was not sandpapered.

[7] Aluminum house paint made with aluminum powder in bodied linseed oil, resin-free vehicle.

Table 4.--The 1944 tests on Douglas-fir plywood covered with resin-impregnated paper.

Painting system[1]			Thickness of coating[2] on -		Performance of coating during exposure facing south[3]			
					On plain plywood		On covered plywood	
First coat- (p/nv)	Second coat- (p/nv)	Third coat- (p/nv)	Plain wood	Covered wood	Rating for coating integrity[4] after 71 months	Durability[5]	Rating for coating integrity[4] after 71 months	Durability[5]
			Mils	Mils				
Sealer (pre)	L (0.30)	L (0.30)	4.6	4.3	Bad	49	Bad	65
Aluminum[6]	do.	do.	4.9	4.5	Fair-	77	Poor+	74
L (0.40)	do.	do.	5.0	4.6	Bad-	52	Fair-	77
L (0.30)	do.	do.	5.3	5.0	Bad-	63	Poor+	74
TL_{29}(e) (0.40)	do.	None	3.0	3.2	Poor-	68	Poor	71
TL_{29}(e) (0.30)	do.	do.	3.2	3.5	Poor	71	Poor+	74
Sealer (pre)	$TL_{28}Z_{28}$ (0.30)	$TL_{28}Z_{28}$ (0.30)	6.0	5.8	Bad	49	Poor-	70
Aluminum[6]	do.	do.	6.4	6.1	Poor	71	Poor	71
$TL_{28}Z_{28}$ (0.40)	do.	do.	6.1	6.0	Bad-	46	Fair+	83
$TL_{28}Z_{28}$ (0.30)	do.	do.	5.9	6.0	Bad-	49	Fair-	77
TL_{29}(e) Z_{28} (0.40)	do.	None	3.6	3.3	Bad+	53	Poor	71
TL_{29}(e) (0.30)	do.	do.	3.7	3.8	Poor-	57	Poor	71
Sealer (pre)	$(TL_{10}Z_{20})_{97}$(0.30)	$(TL_{10}Z_{20})_{97}$(0.30)	5.0	5.2	Bad-	46	Bad	66
Aluminum[6]	do.	do.	5.4	5.7	Poor	71	Poor	71
$(TL_{10}Z_{20})_{97}$(0.40)	do.	do.	5.4	5.2	Bad-	47	Fair+	83
$(TL_{10}Z_{20})_{97}$(0.20)	do.	do.	5.7	6.0	Poor-	58	Poor	71
TL_{29}(e) Z_{97}(0.40)	do.	None	3.6	3.5	Poor	71	Fair+	83
TL_{29}(e) (0.30)	do.	do.	3.8	4.1	Poor+	74	Fair-	77
Aluminum[6]	$(TL_{10}Z_{20})_{133}$(e)(0.40)	$(TL_{10}Z_{20})_{133}$(e)(0.40)	3.7	3.8	Fair-	77	Fair	80
TL_{29}(e) (0.40)	do.	do.[7]	3.9	2.8	Poor-	57	Poor+	74
$(TL_{10}Z_{20})_{133}$(e)(0.40)	do.	do.[7]	4.0	2.6	Bad	49	Fair+	83
Aluminum[6]	$(TZ_{25})_{138}$(pre)(0.31)	$(TZ_{25})_{138}$(pre)(0.31)	3.5	3.6	Fair-	77	Good-	86
TL_{29}(e) (0.40)	do.	do.[7]	4.1	3.0	Fair-	77	Fair+	83
$(TZ_{25})_{138}$(pre)(0.40)	do.	do.[7]	3.9	2.8	Poor+	74	Fair+	83
TL_{29}(e) (0.40)	$(TZ_{25})_{243}$(ar)(0.22)	$(TZ_{25})_{243}$(ar)(0.22)	3.6	2.9	Poor-	65	Fair	80
$(TZ_{25})_{243}$(ar)(0.22)	do.	do.	3.1	2.0	Bad+	57	Bad+	69
TL_{29}(e) (0.40)	T_{246}(ar) (0.22)	T_{246}(ar) (0.22)	3.5	2.9	Poor-	64	Poor	71
T_{246}(ar)(0.22)	do.	do.[7]	3.1	2.1	Poor	71	Fair-	77

[1] For meanings of the symbols for composition of paints see the appendix to this paper.

[2] Coating thickness was calculated by the Forest Products Laboratory method (12) but the resin-impregnated paper covering was considered nonabsorptive. One mil is 0.001 inch.

[3] Northern exposures are not recorded because the coatings did not deteriorate enough in 71 months to permit significant rating.

[4] Successive stages in the deterioration in integrity of coatings are rated good, fair, poor, and bad with the added subdivisions of high (+), medium and low(-) in each stage (4).

[5] The durability is the age of the coating when it was first rated medium poor in integrity.

[6] Aluminum house paint made with aluminum powder in bodied-oil, resin-free vehicle.

[7] The third coat was applied on plain plywood but was omitted on covered plywood.

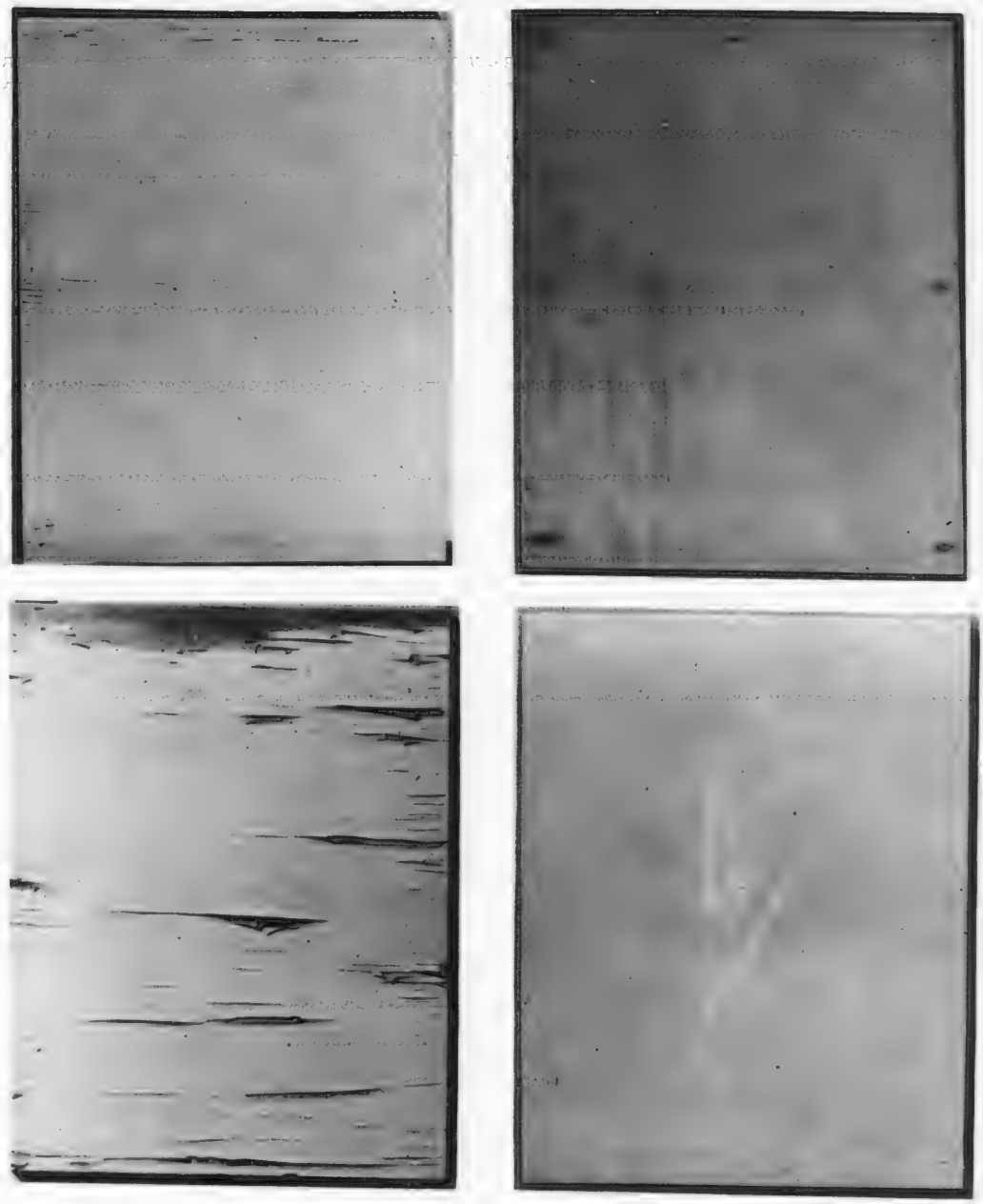

Figure 1.--Better performance of paint and enamel on acetylated than on untreated wood after 4-1/2 years' exposure to the weather vertically facing south at Madison, Wis. The two plywood panels at the left were faced with ordinary sweetgum, and the two at the right with acetylated sweetgum. The two upper panels were painted with house-paint primer $TL_{30}(e)$ and house paint $(TL_{29}Z_{30})_{168}$. The two lower panels were painted with enamel undercoater $T_{33}(e)$ and enamel $(TZ_{15})_{325}(ar)$.

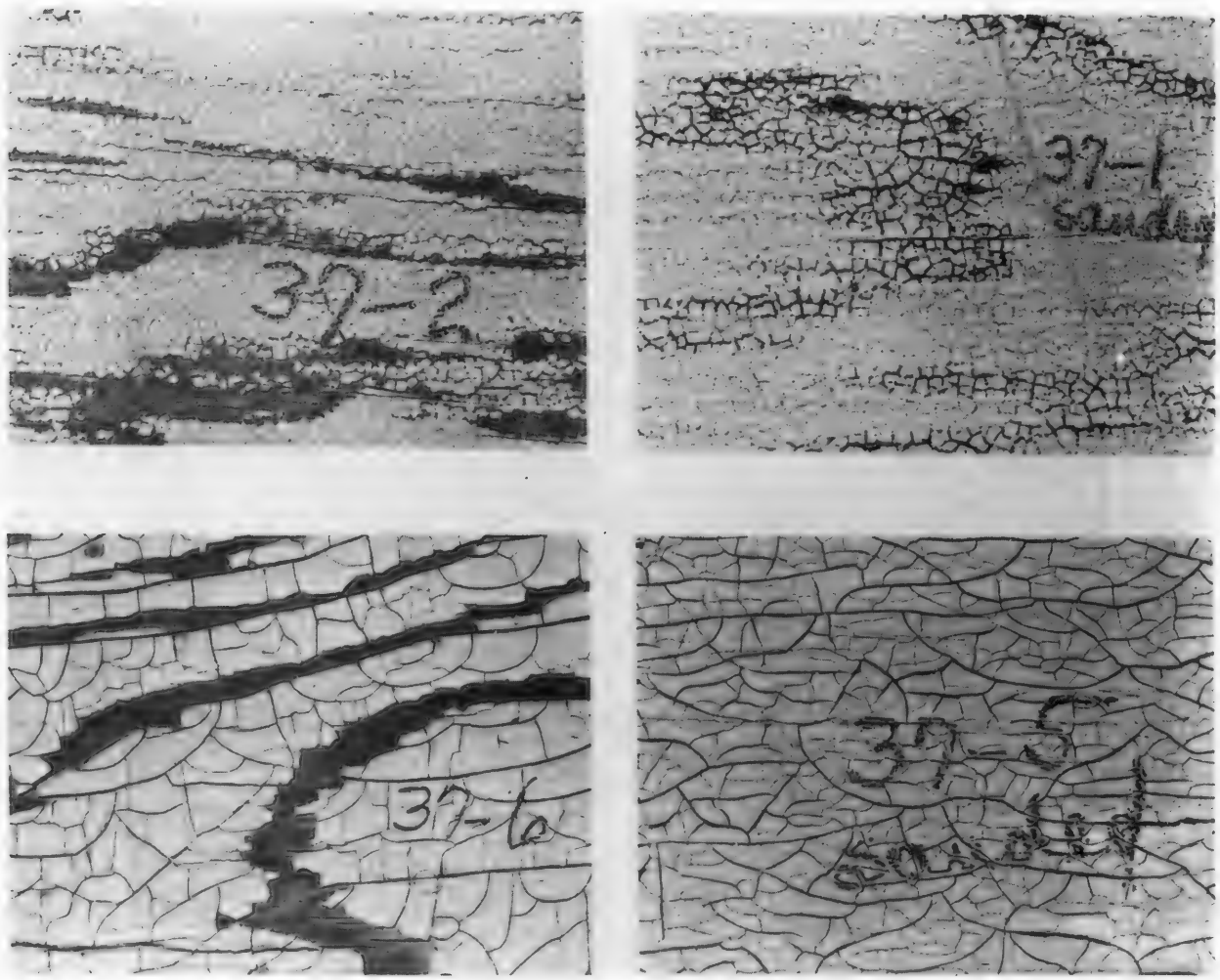

Figure 2.--Condition of house paints on impreg-faced and on plain Douglas-fir plywood after 7-1/2 years' exposure vertically facing south at Madison, Wis. The two panels at the left were plain plywood and the two at the right were plywood faced with impreg. The two upper panels were painted with paint L and the two lower panels with paint $(TL_{28}Z_{28})_{116}$. Impreg prevented crumbling or flaking from summerwood but alligatoring developed on the impreg.

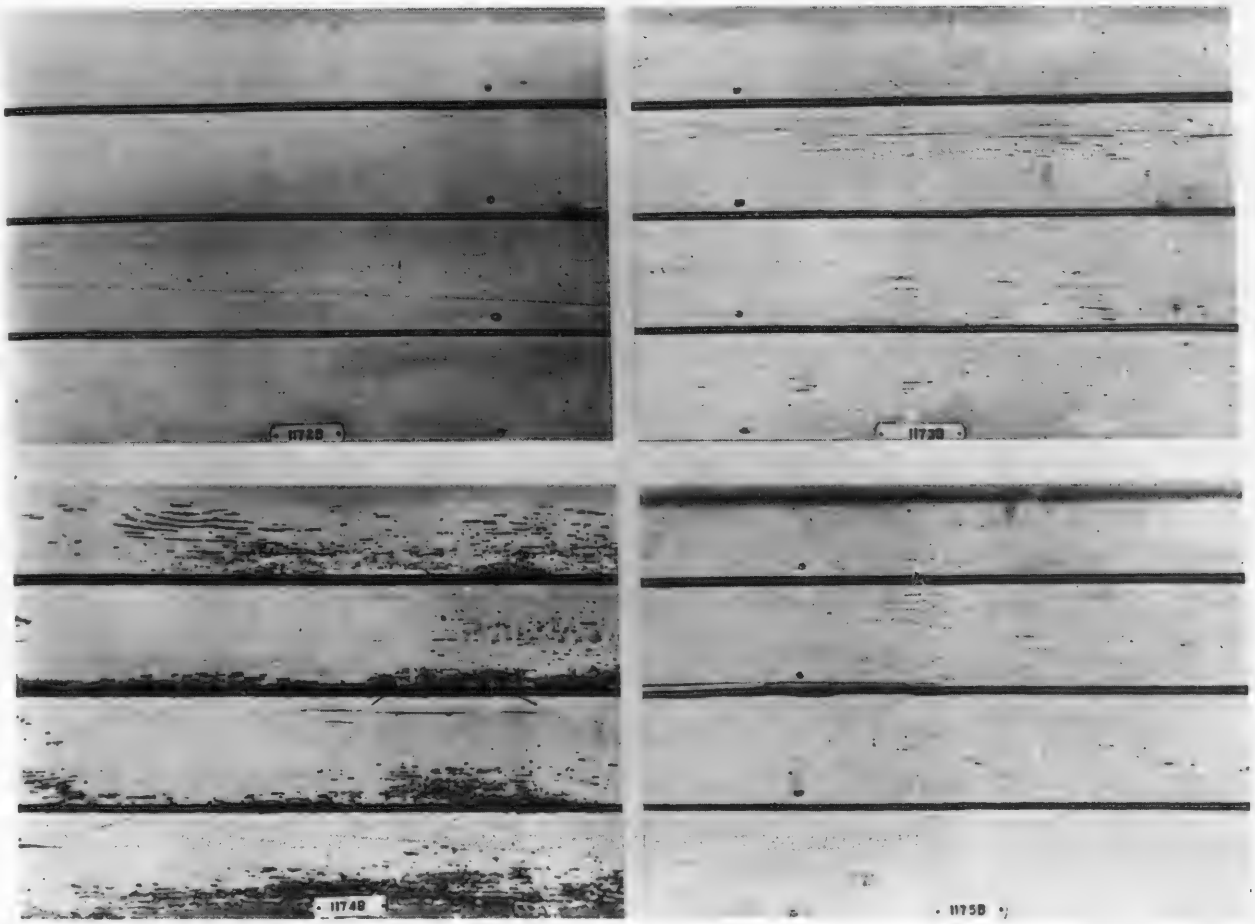

Figure 3.--Performance of paint L on southern yellow pine (the two panels at the right) and on southern yellow pine covered with kraft paper (upper panel at left) or with tissue paper (lower panel at left) after 35 months' exposure at 45° facing south at Madison, Wis. (1932 tests).

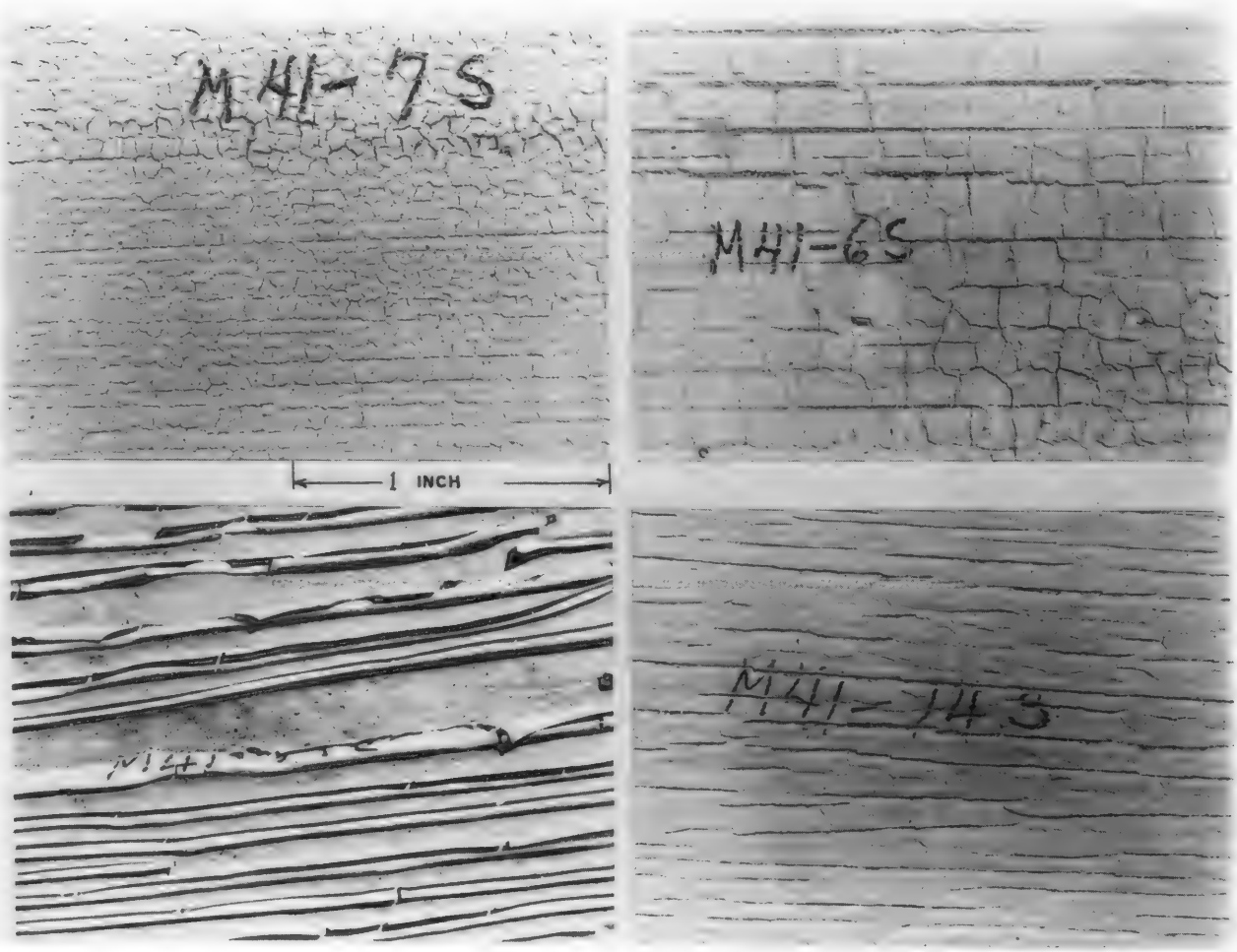

Figure 4.--Condition of some of the coatings of house paint on plywood covered with resin-impregnated pulpboard (tests of 1941) after 28 months' exposure vertically facing south at Madison, Wis. The two upper test areas were coated with paint L, the two lower test areas with paint $(TL_{28}Z_{28})_{116}$. The two test areas at the left were primed with the same paint used for the finish coat; the two test areas at the right were primed with house-paint primer $TL_{28}(e)$.

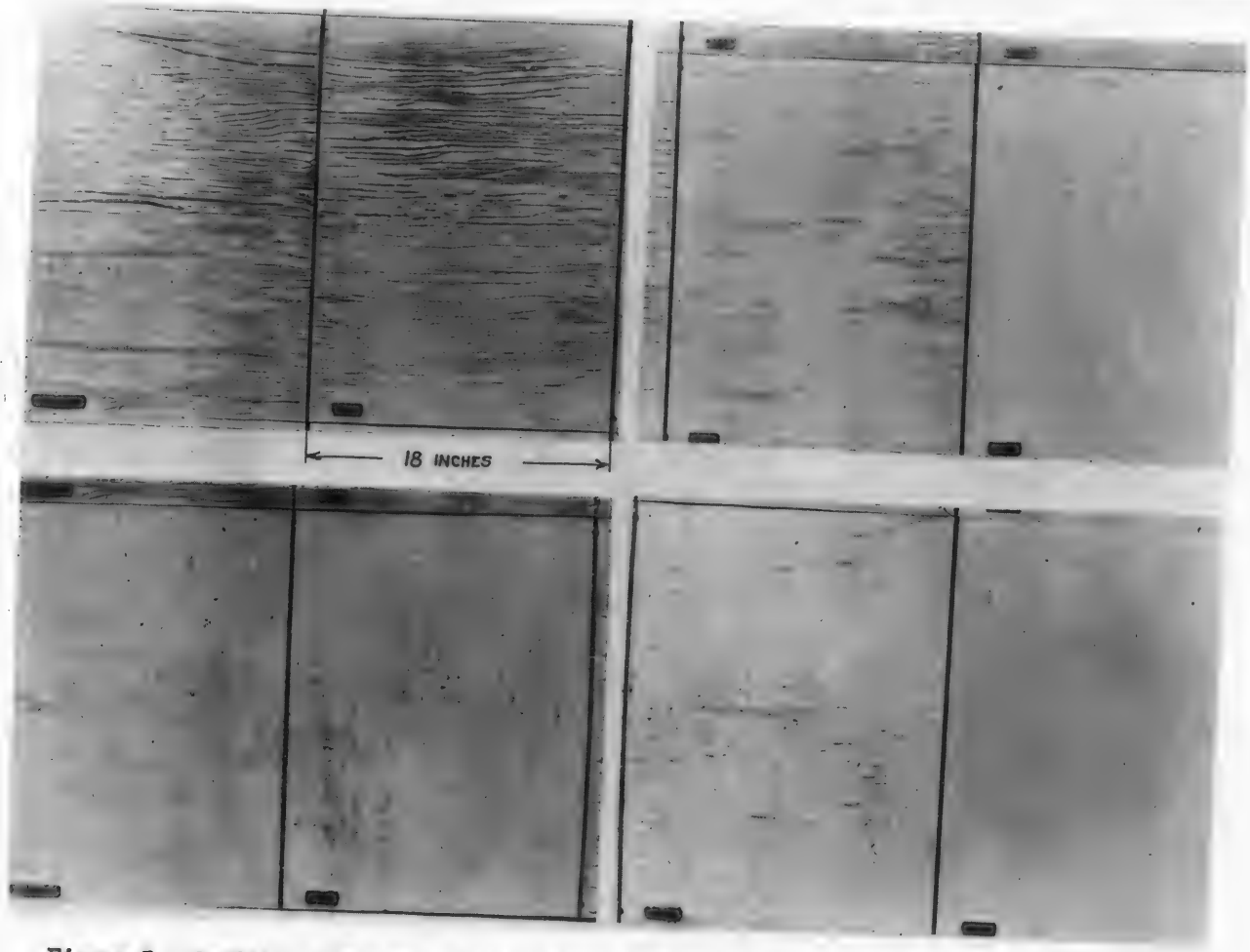

Figure 5.--Condition of some of the coatings of enamel on plywood covered with resin-impregnated pulpboard (tests of 1941) after 40 months' exposure vertically facing south at Madison, Wis. The upper test areas were coated with enamel $(TL_{20}Z_{30})_{126}(e)$, the lower test areas with enamel $T_{420}(ar)$. From left to right the four upper test areas were primed with the finish enamel, undercoater $(TL_{20}Z_{10})_{78}(e)$, house-paint primer $TL_{28}(e)$, and aluminum primer, respectively; the four lower test areas were primed with undercoater $T_{144}(e)$, the finish enamel, house-paint primer $TL_{28}(e)$, and aluminum primer, respectively.

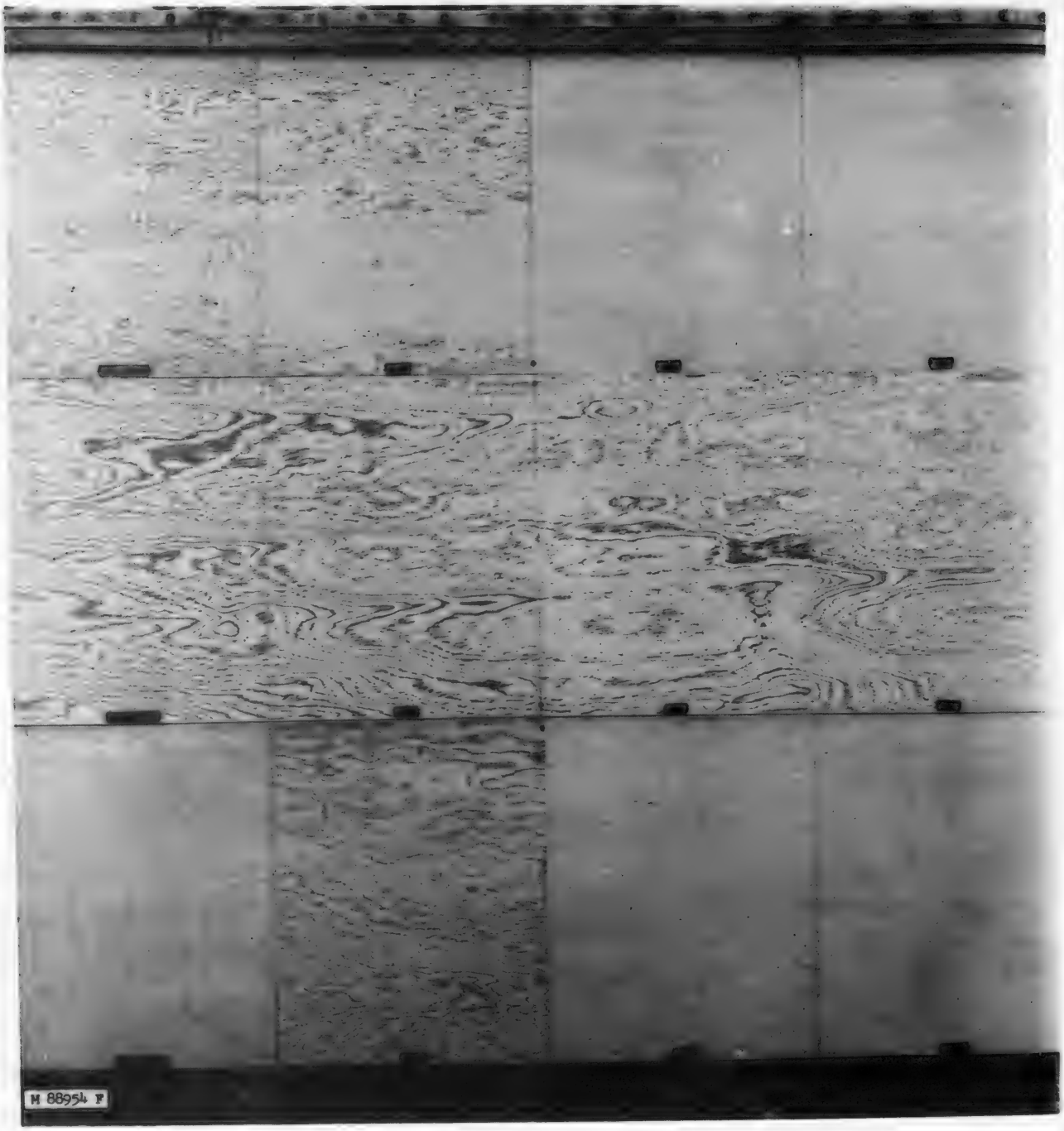

Figure 6.--Condition of paint on plain Douglas-fir plywood in the 1944 tests of plywood covered with resin-impregnated paper (see fig. 7) after exposure vertically facing south for 71 months at Madison, Wis. The top and middle rows of four test areas each received a priming coat followed by two finish coats of paint L; the bottom row of four test areas received a priming coat followed by one finish coat of paint L. From left to right the priming coats on the top row of test areas were wood sealer (pre), wood sealer (ar), aluminum in bodied linseed oil, aluminum in phenolic-resin varnish; on the middle row paint L with p/nv 0.50, p/nv 0.40, p/nv 0.30, p/nv 0.20; and on the bottom row house-paint primer TL_{29}(e) p/nv 0.50, paint L p/nv 0.40, primer TL_{29}(e) p/nv 0.40, and primer TL_{29}(e) p/nv 0.30.

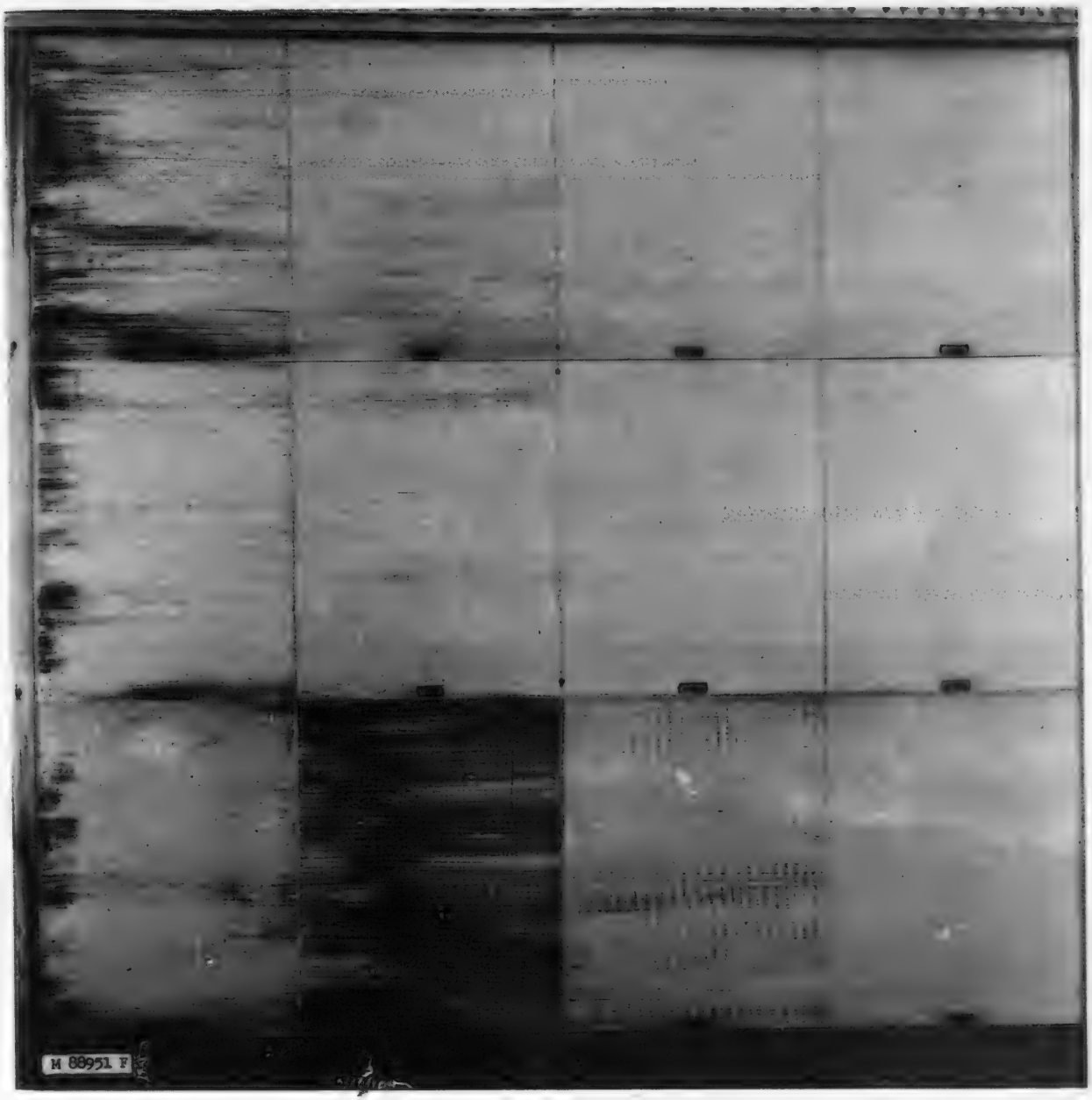

Figure 7.--Condition of paint on plywood covered with resin-impregnated paper in the 1944 tests after exposure vertically facing south for 71 months at Madison, Wis. The primers and paints and their arrangement on the test areas were the same as they were on the plain plywood shown in figure 6.

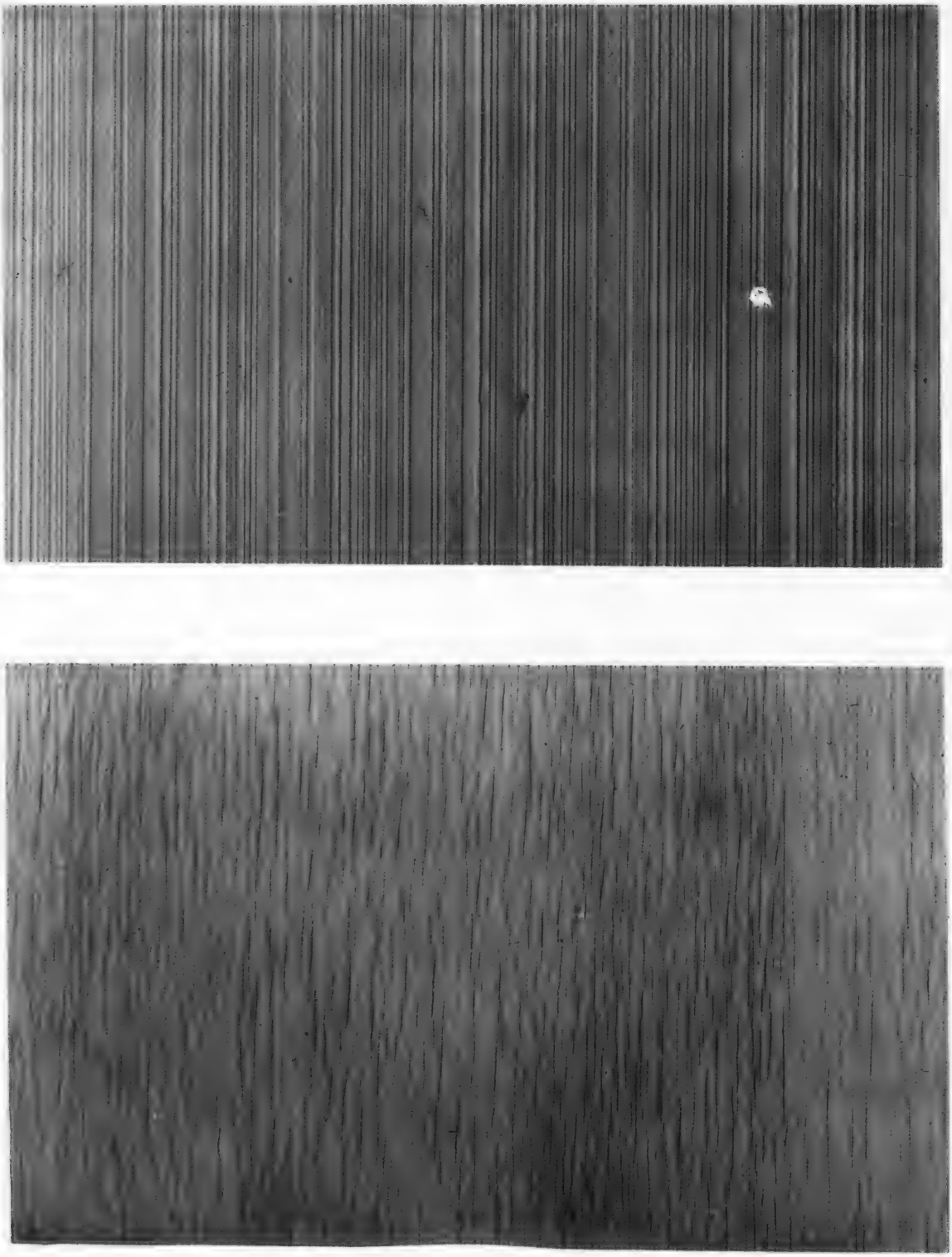

Figure 8.--Superior performance of paint on striated Douglas-fir plywood as compared with plain plywood. Both views were taken on parts of the same building in southern Arizona that were last painted about 2 years previously with the same kind of paint. Note that the striated plywood shows no face checking as well as superior coating integrity, whereas the plain plywood checked very badly.

Panel Discussion on Characteristics of Film Forming Materials

1. Use of Drying Oils as Protective Coatings for Forest Products[1]

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Drying oils are the only materials either natural or synthetic that display the phenomenon of transformation from a liquid to a solid when exposed to air in thin films. Because of this property, drying oils form the backbone of the protective coating industry. Acrylic and vinyl resins do not use fatty oils or fatty acids, and although epon resins and latex emulsions may be used without drying oils, some of their properties may be improved through use of this class of materials. Alkyd resins and phenolic resins are essentially means of modifying drying oils.

COMMERCIAL DRYING OILS

Although literally hundreds of oils from various vegetable, animal, and marine sources have at one time or another been tried and sometimes used as drying oils, a relatively small number constitute the bulk of our commercially important oils for use in protective coatings. Linseed, tung, dehydrated castor, fish, soybean, and tall oils make up a large proportion of the billion pounds of drying oils used in the paint and varnish industries and the closely allied linoleum and printing ink industries.

The oils of importance for protective coatings must be readily available in a stable harvestable crop that can be commercially processed to give good yields of oil and readily saleable by-products. Drying ability is of secondary importance since chemical modification can convert a semidrying oil such as soybean oil into our second most important drying oil, and can even up-grade cottonseed oil to give useful coating materials.

The price of oils is not a primary factor in itself, but is largely governed by the items mentioned above--ready availability of raw materials, easy extractibility to give good oil yields, and economically valuable by-products. If the price of soybean oil were the same as linseed, we should find relatively little used in protective coatings. If tall oil were priced the same as linseed oil, we should probably find that not one drop would go into protective coatings. The cost for modifying such poorer drying products as soybean oil and tall oil for drying oil purposes would make their use prohibitive in paint products if they did not enjoy a price advantage over better drying materials. Soybean oil can be produced at a lower cost per unit weight than linseed, and even after relatively costly chemical processing, there is normally a cost advantage in favor of the soy bean product.

EXTERIOR FINISHES

Exterior finishes are almost always pigmented since durability of clears is rather poor under exposure to sunlight and rain. Linseed oil is the standard of quality in house paints, but recently maleic modified soybean oils have been developed that can be used almost interchangeably with linseed oil. During the past ten years there has been a distinct change in house paint formulations. Pre-war products were based on raw linseed oil or raw oil plus at most 10 percent of bodied oil. Such paints had inherently good durability, but the typical buttery consistency of raw oil resulted in paints with poor flow characteristics. The films leveled poorly and retained brush marks. Erosion of the paint in the valleys resulted in faster deterioration than would be observed if the same quantity of paint were applied in a perfectly smooth film.

Addition of heat-bodied oils led to improved leveling and consequently improved durability. Bodied oil addition also permitted economies in manufacture since higher pigment loading is practical without loss of gloss, durability or suitable application consistency. Hiding and cleaning are improved.

The typical pre-war house paint containing at most 10 percent of bodied oil was formulated at a PVC (pigment-to-vehicle ratio) of 29 percent, that is, 29 percent of the volume of the final dried film was pigment. Modern house paints use from 30 percent up to 50 percent of bodied oil and are formulated at PVC's of 31 to 35 percent and up to 40 percent in unusual cases with substantial increases in high hiding prime pigments and substantial reduction or even elimination of lead. The pre-war three-coat house paint system has been replaced by the two-coat system which was a pre-war novelty. Now a one-coat repaint system is being sold.

[1] Presented at meeting of Forest Products Research Society, Pacific Northwest Section, May 20, 1952, Portland, Oregon.

An interesting current phase of house paint research involves stainproof systems in which lead and zinc have been eliminated entirely using only prime pigments and inerts with hard drying resin or copolymer modified vehicles. Mildew is a problem in such products.

Barn paints are formulated in much the same way as house paints. However, color is not an important characteristic and the inherently better durability of iron oxide pigmented paints over the conventional whites used in house paints permits increased use of lower cost ingredients. Considerable quantities of fish oil, tall oil, and relatively inexpensive blown oils are used in most barn paints, together with cheaper grades of resins.

Exterior trim paints require gloss retention not commonly possessed by house paints. Long oil varnishes or alkyds are the most common vehicles.

Shingle stains are largely oil-based, but recently there has been increased interest in copolymer vehicles to speed up manufacture of colored shingles. Quite similar vehicles are used as tempering oils for hardboards. These materials act essentially as penetrating sealers increasing scuff resistance and water resistance and giving improved dimensional stability when the wood is exposed to moisture or high humidity.

Clear exterior finishes are relatively unsatisfactory. Film deteriorating sunlight penetrates deeply and causes rather rapid film breakdown in the absence of light reflecting or light absorbing pigments. Staining from moisture occurs as film integrity is lost. A variety of vehicles are used in exterior clear sealers including unmodified oils; long oil varnishes, especially tung based products; alkyds and copolymer oils. All of these products are thinned to rather low non-volatile contents to decrease viscosity and increase penetration into the wood.

INTERIOR FINISHES

Vehicles used for interior finishes have a much wider range of performance requirements than exterior vehicles whose primary requirement is durability.

Enamel undercoaters are the normal first coat on interior pigmented architectural trims. Vehicles for these paints must have good nonpenetration to avoid porous, pigment-rich vehicle-poor films. If penetration of vehicle into the bare wood is excessive, the resultant porous film sucks vehicle from the finish coat resulting in flatting and streaking. Limed oils in which calcium soaps are dispersed in a bodied oil vehicle to give a heavy grease-like consistency even at low nonvolatile content are the most popular vehicles for enamel undercoaters. Hardening agents such as resins, varnishes, copolymer oils or alkyds are added to give good sanding properties after relatively short drying periods. Other nonpenetrating vehicles include copolymer oils, heavily bodied alkyds and catalytically polymerized oils.

The finish coat for interior architectural trim must possess good color and color retention, good gloss retention, fair alkali resistance and fair flexibility. Whites or light colored tints are usually based on soybean oil or dehydrated castor oil. Both of these oils can be cooked to give pale, color retentive varnishes or the oils may be used as bases for copolymers or alkyds. Maleic modified soybean oils have become very popular varnish oils giving faster processing and lighter color than can be obtained with unmodified soybean oil. Clear blond finishes for interior trim are based on the same vehicles as the pigmented white enamels. A large variety of oils including linseed, fish, tung, and tall oil are used in darker pigmented glosses and semi-glosses, demanding less in the way of color retention during film aging.

Floor enamels are usually pigmented in rather dark colors and the vehicles do not require color retention commonly demanded of architectural trim enamels. Major vehicle requirements include fast drying to give hard, tough, abrasion-resistant and alkali-resistant films. Linseed-tung-phenolic or modified phenolic varnishes are the classical vehicles but copolymer vehicles and alkyds are available which give excellent performance. Epon esters give excellent alkali resistance and toughness.

Clear varnishes for floors are usually based on essentially the same vehicles as the enamels although increased use is made of soybean oil and dehydrated castor to give optimum color retention. Floor seals are a specialized finish requiring positive drying and low viscosity to give maximum penetration. Medium length soybean and dehydrated castor varnishes are used to give good color retention and tung oil is frequently used as a portion of the oil to give improved resistance to water spotting or alkaline cleaning agents.

Porch and deck enamels are quite similar to floor enamels. They are somewhat higher in oil content to give improved flexibility and better durability.

Painting wood-based soft board presents problems akin to those in painting plaster. Because of the porosity of the substrate, the vehicle should have good non-penetration. Wall primer sealers utilize vehicles similar to those used in enamel undercoaters such as limed oils, high viscosity copolymers and alkyds, and catalytically polymerized oils. Since there is no sandability requirement, little or no hardening agent is used. Clear sealers based on the above vehicles give excellent performance as undercoaters for heavily pigmented products such as flats, whereas the pigmented wall primer sealer is more practical, using less heavily pigmented semigloss or gloss enamels as topcoats. Resin emulsions, varnish emulsions and latex emulsions are also used as vehicles for flat finishes.

Oleoresinous systems are used to only a limited extent as clear furniture finishes. Top quality rubbing varnishes still make use of natural resins, but clear furniture finishes are now largely based on nitrocellulose lacquers in which drying-oil-based plasticizers are frequently important components.

FUTURE DEVELOPMENTS

Because of their unique properties, it is not likely that drying oils will be supplanted by synthetic materials in the near future, and total replacement may never occur. However, the continuing pressure of the chemicals industry is leading to increased research on drying oils which, in turn, is paying dividends in products of improved quality.

In the future, drying oil fatty acids will be used as a chemical raw material rather than as the primary product. Copolymer and chemical modification should lead to vastly improved coating materials. We believe the use of new chemical intermediates, which are being developed almost daily by the chemical industry, will provide many new and unusual possibilities for drying-oil modification. Products of improved quality can be anticipated.

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2. Latex as a Film Forming Medium for Surface Coatings[1]

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INTRODUCTION

Since it does not refer exclusively to a type of resin associated with certain class of chemical building blocks, the term latex can perhaps better be used to describe a method of coating application. In terms of wood finishing, therefore, let us first examine what a latex is and how it forms a film. The original meaning of the term latex as natural rubber milk has given way to a broader usage in which it represents any dispersion of high-polymer solids of very small particle size in water. This is the common denominator around which we can build a discussion of the properties afforded by this type of film deposition and the variables that can be employed in influencing these properties.

VERSATILITY OF THE PROCESS

The number of possible combinations of building blocks for resins to be used via the latex method is very large. By varying the type and amount of these monomeric building blocks, we can obtain deposited films varying all the way from soft, sticky materials as cast from some types of GRS (synthetic rubber latex) to hard, brittle materials like 100 percent polystyrene latex, that will not form a continuous film at room temperature without heating or modification with other materials. A few of the monomers that can be used to vary these properties are acrylic acid esters, butadiene, styrene, vinyl acetate, vinyl chloride, vinylidene chloride, and others. These can be polymerized with themselves or copolymerized with one or more of the others. Many of these are familiar to everyone in the form of resins used to make a large variety of molded plastic articles. Among the properties other than film hardness or pigment binding strength, which can be built in or varied through monomeric variation, are fire, chemical and abrasion resistance, color stability, and compatibility with other materials. Another characteristic of the latex method is the wide latitude in molecular weight (and resulting intrinsic viscosity) which the dispersed resin can have without becoming hard to handle. In other words, a latex affords a method of using high-molecular weight, tough polymers dispersed at high solids content (50 percent or greater in many cases) without regard for the fact that such materials in molecular solution in solvent systems give solution viscosities that are out of range for easy application characteristics and in many instances exist only in the form of gels at such concentrations. A third, rather obvious, characteristic of latexes is that water is a cheap, universally available, nonflammable, odorless, dispersion medium. Latexes, therefore, permit the formulation of water-dispersed coating mixtures that will deposit water-resistant dried films.

HOW THE FILM IS FORMED

It may next be appropriate to ask the questions: How does this film formation come about, how does it differ from the way in which other materials form their films, and what are the properties afforded by the latex method? The two most familiar film-forming processes that are widely in evidence in wood finishes are those of chemical change and evaporation. Chemical change is an old story to anyone who has ever used a paint, varnish, or enamel, in which the film forming takes place by further polymerization with the aid of atmospheric oxygen. Nitrocellulose lacquers are an example of the second mechanism, in which evaporation of the solvent leaves a resin film without the aid of any further chemical change. The latex mechanism is a combination of the latter and a third one which we can call fusion, in which the discrete, dispersed resin particles coalesce, or fuse, into a continuous film. The essential result is a quick-drying film which can be cast from a medium having high solids content and low viscosity.

OUTLINE OF DEVELOPMENTS TO DATE

What have these various characteristics meant in terms of properties associated with them and applications in which they are now being used successfully, or show promise of being useful, in coatings and finishes? The latex technique is still very young in comparison with most of the others and the relatively small number of fully matured applications mean that there is still a vast amount of evaluating work to be done. The first of the mature applications was started about 1947, when the nonpenetrating, self-sealing qualities of some latexes were found to be useful for formulation of base coatings for textiles of the table oilcloth variety. Pigment-binding qualities of

[1] Presented at meeting of Forest Products Research Society, Pacific Northwest Section, May 20, 1952, Portland, Oregon.

latex films were first utilized about that time in adhesives for clay coating fine printing paper and decorative washable coatings for insulation board. Early in 1949 the first interior latex paint was offered for sale and since that time the growth of these paints has been so fast that they are now being produced at a rate of about 22,000,000 gallons per year. Most of this paint has been applied to interior wall surfaces such as plaster and plasterboard where the quick drying, ease of washability, low odor level, and several other factors have made them popular. A fair amount of interior woodwork has also undoubtedly been painted with latex paint, but this has not been promoted to the extent of wall-finishing by the manufacturers.

From here on we anticipate an expanding technology in the use of latex for an increasing number of finishing applications. Among these are paints for exterior applications, the possibilities of which have recently received a certain amount of publicity. It should be emphasized that these paints are in the very early stages of development and that a long period of testing will be necessary before we can be sure of their behavior.

FUTURE POSSIBILITIES

In addition to exterior exposure tests of latex paints on both wood and masonry surfaces, two other developmental applications of latex in finishing forest products may be of interest. The first of these is in the sealing of the rather porous surface of hardboard for the purpose of holding out paint or varnish films which are later applied. The possibility of a grade of hardboard primed at the mill with a latex sealer coat is being investigated. Here the powerful film-forming properties of latex are advantageous in thoroughly sealing the surface of the board with a very light application and without appreciably changing the appearance. Also currently under development is the modification of intumescent or other fire-resistant coatings for insulation board with vinyl-type latexes as an aid to non-flammability and scrub resistance. Some other possibilities for development of latex in wood finishing are special chemical and abrasion-resistant latex paints for hardboard and semi-mastic type texture finishes for various kinds of composition board where specialty effects are desired.

There are, therefore, two general points to be held in mind when considering the utility of the latex method for a particular application:

1) The desirability and practicability of a water-based system.
2) The particular properties desired in the coating, which will determine what type of water-dispersed synthetic high polymer is to be selected.

The results will then depend upon formulation and application technique.

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3. Phenolic Resin Finishes[1]

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Usually, when the paint or resin chemist speaks of phenolic resin finishes he has in mind what is known as an "oil-soluble" phenolic resin cooked with a modifying oil and usually dissolved in a volatile thinner. Finishes of this type are usually referred to as "pure" or "100 percent" phenolic varnishes if they are transparent, or as enamels, if pigmented.

VARNISH CHARACTERISTICS AND NOMENCLATURE

First of all we may say that a varnish is a dispersion of resinous material in an oil and this dispersion is usually dissolved in a volatile thinner. The oils generally possess "drying" characteristics and the resinous material may be either a natural or synthetic material. The quantity of oil present in such a varnish is denoted as its "length" which expresses the ratio of oil used, measured in gallons to 100 pounds of resin. Thus, since most oils weigh approximately 8 pounds per gallon, a 12.5-gallon-length varnish contains approximately 100 pounds of oil for each 100 pounds of resin and is therefore approximately 50 percent oil. Similarly a 25-gallon-length varnish contains 200 pounds of oil per 100 pounds of resin and therefore contains 66-2/3 percent oil.

Varnishes are classified as "short" at lengths less than 15 gallons, "medium" from 15 to 30 gallons and "long" at lengths greater than 30 gallons. Another method of classification is by end use such as "rubbing or furniture" (short to very short oil type) "floor or interior" (15 to 25 gallons) and "spar" (25 gallons or longer).

All of the foregoing classifications are only approximate and the actual utility of a varnish depends not only on its length but also on the type of resin and oil used and also on the technique employed in producing the varnish.

MODIFYING PHENOLIC FINISH CHARACTERISTICS

The common phenol formaldehyde resins are not soluble in drying oils and they must therefore be modified to produce this solubility. One of the first methods of doing this was to flux the phenolic reaction product with rosin. The resultant resins however had bad yellowing characteristics and would yield films that discolored badly. It was found later that by using substituted phenols, that is, chemical compounds of phenol and other non-resinous chemicals, it was possible to produce resins that were also soluble in oils and contained no rosin or other natural resins. It was also demonstrated that if the substituted group was in what the chemist calls the "para" position on the phenol molecule, and other phenolic bodies were not present, the color and color retention of the product were vastly improved. We therefore find on the market numerous phenolic resins made from para-substituted phenols. The most frequently encountered substituting groups are phenyl, tertiary butyl, tertiary amyl, or terpene, radicals. Which particular phenol or combination the resin chemist uses depends on the results he wishes to produce and on their relative costs.

In the manufacture of the 100 percent phenolic resins, the chemist also has a choice of conditions under which his chemicals can be reacted. Thus, one item of difference would be the catalyst used in making the condensation that changes liquid, crystalline, or gaseous chemicals into resinous bodies. These can be either acids or alkalies and here, too, in each group he has a wide field of types and quantities to be employed. Both groups of catalysts are used industrially. The alkaline catalysts yield resins that foam in the presence of heat and react with the conjugated oils. This type of phenolic resin is used either to produce long-oil spar varnishes of the harder drying oils, like china wood or oiticica, or it is mixed with other resins to raise their melting points when shorter oil length varnishes are made.

The acid-catalyzed phenolic resins are much more popular with the varnish chemist in that they do not foam and are much easier to handle in the varnish kettle. They can be used with a greater variety of oils and at any oil length, from very short to extra long.

In addition to the 100 percent phenolic resins discussed previously, numerous oil-soluble modified phenolic resins are available. This classification usually denotes that the

[1]Presented at meeting of Forest Products Research Society, Pacific Northwest Section, Portland, Oregon, May 20, 1952.

phenolic resin is reacted with another resin such as ester gum, copal or a similar natural resin. Here again the resin chemist has a wide choice of reactants, proportions and methods of combining his raw materials to produce the end product he hopes will fit the needs of a particular field of application. In making modified phenolic resins the chemist can use still another pure phenolic body -- bis-phenol. This product will flux with rosins and some of the other natural resins but it is not soluble enough, by itself, to produce a "pure" oil-soluble phenolic resin.

The Epon resins, one of the newest members of the pure phenolic resin group, are reaction products of bis-phenol and epichlorohydrin rather than an aldehyde, which is normally used as the resinifying agent. The chemical composition and properties are, therefore, different and we have available in them a new variety of exceptionally interesting compounds.

So much for the resins themselves and the job of combining the resins with the oils - the job of the varnish chemist. The resins and finishes made from phenolic derivatives are characterized by resistance to chemicals, to water and to weathering. Since this is a characteristic of the phenolic portion of the finish we would naturally expect that these characteristics are enhanced by the presence of higher proportions of the phenolic resin. However, the phenolic resin portion of such finishes is generally friable and brittle so we find that increasing the phenolic portion at the expense of oil in a varnish decreases flexibility. The speed of setting and drying to final hardness is, however, increased by this same change.

If on the other hand, we are considering varnishes made with modified phenolic resins and we change the phenolic content at the expense of the modifier -- usually ester gum -- but keep the oil content the same, then an increase in phenolic content not only gives improved resistance to chemicals, water and weathering, but also gives improved flexibility with little or no change in drying characteristics.

Previously, in discussing the classification of varnishes, I mentioned that such classifications were only approximate and that other factors entered into the choice of a varnish for a given job. One such factor is the continued improvement in quality and lowering of cost being achieved in various products. Thus, modified phenolic resins are now available that approach pure phenolics in chemical resistance. Then, too, we now have pure phenolic resins that approach the modified phenolics in cost. So that, all in all, it is difficult to arrive at a clear cut decision as to which type will give the best results.

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4. Epon Resins for Surface Coatings[1]

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INTRODUCTION

Undoubtedly, many of you have heard of the new series of resins manufactured and marketed by Shell Chemical Corporation under the trade name "Epon Resins". For those of you to whom the subject is unfamiliar, and as a summary for those of you who are already acquainted with them, I would like to tell you about these new products and their outstanding properties, to outline where the Epon resins are currently being used, and to mention those applications where, we believe, they will be used in the future. Insofar as possible, I shall try to cover points of particular interest to you as manufacturers of wood products -- asking, at the same time, that you bear in mind that many uses for these resins are still in the rather early stages of development.

EPON RESINS - THEIR NATURE AND PROPERTIES

The Epon resins represent an entirely new class of condensation polymer (made from epichlorohydrin and bisphenol) possessing both reactive hydroxyl and epoxide groups. Surface coatings made from these new resins exhibit an unusual combination of properties:

A. Excellent adhesion.
B. Outstanding flexibility.
C. Superior chemical resistance.

In typical structure as postulated for the Epon resins, the only bond, other than carbon-to-carbon, in the linear polymer is an ether linkage. An ether linkage, in contrast to an ester group, is extremely resistant to chemical change. The reactive hydroxyl and epoxide groups are widely spaced along the chain, so that the curing agents which cross-link the resin and make it thermosetting are sufficiently far apart to give rise to the unusual flexibility exhibited by the cured resin. The polar nature of the molecule makes possible the outstanding adhesion.

Let me emphasize these characteristics again:

A. Chemical resistance because of ether linkages.
B. Flexibility by virtue of widely spaced cross-linking units.
C. Outstanding adhesion because of the polarity of the molecule.

Epon resins exhibit generally good color and color retention, because of the absence of phenolic hydroxyl groups, as such.

EPON RESIN FINISHES

We can similarly summarize the outstanding properties of finishes made from Epon resins:

A. Adhesion. Finishes made from Epon resins give outstanding adhesion over wood and metal surfaces, even without the customary priming or prechemical treatment. A simple cleaning or sanding operation is generally sufficient.

B. Flexibility. Finishes containing Epon resins show a combination of excellent hardness and unusual flexibility, so that they will withstand both a 28 inch-pound direct bump and reverse bump on a Gardner impact tester.

C. Chemical Resistance. Finishes properly formulated with Epon resins exhibit very high resistance to an unusually broad range of agents, including household chemicals, common acids, solvents, alkalies, soaps and detergents. The ability of Epon resin coatings to withstand alkalies, soaps and detergents is truly remarkable. Even the Epon esters, which represent the Epon resin modified with fatty acids, show outstanding resistance to detergents.

MODIFICATION OF EPON RESINS IN SURFACE COATINGS

A. Unmodified Form. The Epon resins may be used in surface coatings in the so-called unmodified form, where they are cold cut in a suitable solvent mixture and then combined with a resin which will react with the hydroxyl and epoxide groups, thus cross-linking the polymer. Urea-formaldehyde, melamine-formaldehyde and certain phenol-formaldehyde resins may be used to cure the Epon resins. This type of Epon resin formulation requires heat to bring about the reaction and curing, and such finishes are used as metal decorating and appliance finishes, can and container coatings, drum coatings, wire enamels, and for other applications where outstanding adhesion and flexibility, toughness and

[1]Presented at meeting of Forest Products Research Society, Pacific Northwest Section, May 20, 1952, at Portland, Oregon.

chemical resistance are desired.

B. Modifications with Fatty Acids. Epon resins may be reacted with various fatty acids under regular varnish cooking techniques, to produce Epon esters. If drying-oil fatty acids, such as linseed, dehydrated castor or soya are used, the resulting vehicle may be air-dried. These air-drying Epon esters are being used in floor varnishes, spar varnishes and other trade sales items. If slow or non-drying fatty acids are used, the resulting esters are combined with melamine- or urea-formaldehyde resins to make baking enamels. This latter type of finish is being used on appliances where it exhibits exceptional resistance to soap and detergent solutions, extreme toughness and flexibility, together with the excellent adhesion previously mentioned.

A recent development in the Epon ester field is that involving the styrenation of Epon resin esters. Styrenated Epon resin esters combine very rapid drying, together with good exterior durability, excellent alkali resistance, flexibility, hardness, and water resistance. This type of coating has been suggested for clear varnishes, forced dry wood finishes, baking enamels, and quick-drying industrial enamels. Our laboratories are continuing work on styrenated Epon esters and their future looks promising.

C. Room-temperature Curing with Amines. A third method of producing a surface coating from the Epon resins, representing a very recent development involves the use of an amine curing agent. Our objective here was to produce a finish with maximum chemical resistance without use of heat. Since the addition of an amine curing agent to the Epon resins sets up a cross-linking action which proceeds immediately at room temperature, a serious application problem arises. One solution to the problem of short pot life has been the development of a special spray-gun to mix the catalyst with the resin in the spray cone as it leaves the gun. Such guns are now commercially available. This type of coating, we believe, will find application in industrial exposure conditions where it is desired to obtain very excellent chemical resistance, but where it is not possible to bake or heat the coating in order to cure it. Since this type of application is quite a new concept, it is too early to forecast all of the various uses to which it may eventually be put. Certainly it is not outside the realm of possibility that this type of application might find an outlet in the wood-finishing field, possibly in the furniture industry where adaption to production line techniques appears feasible.

SUMMARY OF CURRENT USES IN THE FOREST PRODUCTS INDUSTRY

Let us then summarize those applications which have been found to date for the use of Epon resin coatings in the lumber, plywood, and hardboard industries.

A. Epon Esters in Floor Varnishes and Gymnasium Finishes. Epon Esters are being quite widely used in floor varnishes and in gymnasium finishes, and make a definite contribution to this type of finish. In the first place, Epon finishes make use of domestic oils, i.e., linseed oil and its fatty acid, whereas the present standard finishing systems which have been of the general class affectionately referred to as "tung-phenolic" require imported oils. There is much thinking in the industry and much research going on to eliminate or reduce to a minimum the use of tung oil from these finishes because of the erratic supply and indefinite future of this product. Domestic tung oil is produced in the Southeastern United States, but practically all of this is earmarked for specific Government specifications and, for the next several years, there is little likelihood of any heavy increase in production; also, there is much speculation pricewise on tung oil and you will find that it varies anywhere from 25 to 30 cents per pound to as high as 50 to 60 cents per pound.

It so happens that practically all of the phenolics presently used in conjunction with floor finishes have been designed to cook and work well with tung oil only. Deviations, where the predominance of the oil is other than tung oil, result in a serious loss of drying capacity by the vehicle. Such a varnish is not suitable for marketing. This drier absorption has not been overcome. The closest approach to the combination of toughness, speed of drying, water and chemical resistance of the tung-phenolic system is the Epon-linseed system. The tung-phenolic system dries tougher overnight, but both systems are equally tough in, say, 72 hours. The advantages of the Epon system versus the tung-phenolic system are:

> Better color, better color retention, better gloss, better gloss retention, less skinning and better alkali resistance. The speed of drying, water resistance, etc. are about equal. Therefore, it appears that Epon can contribute much to the field of floor and gymnasium finishing. As a result of two years in the field, many manufacturers have reported up to 50 percent less maintenance due to the fact that the floor finish containing Epon has less tendency to show "burns"

where rubber-soled shoes are used (such as in a gymnasium) than the conventional floor finish. It is likewise less slick; therefore, easier to walk on. It should be pointed out that last year the Los Angeles County Public Schools were supplied Epon floor finish. This was done on open competitive bid and the Los Angeles County Schools' Commission had no knowledge that the finish they were using contained Epon other than that the finish met their specifications.

B. Epon Esters in Spar Marine Varnishes. It is apparent from the above that many formulators and manufacturers of this type of finish should immediately review Epon esters for spar or marine finishing. Epon esters are having ever widening acceptance in this field. More and more manufacturers are switching their systems to Epon esters, drawing away from the tung-phenolic field.

C. Epon Resins in Furniture Finishes. In the past, fast drying, forced drying, or air drying finishes for furniture have been made from tung oil modified phenolic varnishes, from pentaerythritol-maleic dehydrated castor oil finishes, and from alkyd-urea or melamine types. If these finishes were not air dried for definite periods of time, they were force dried in oven temperatures ranging from 120° to 150° F., and periods of 90 minutes to 60 minutes. Many Epon esters from linseed, rosin, and tall oil make excellent furniture finishes either with or without urea. They generally exhibit high gloss, excellent hardness, toughness, rubbing and polishing properties, together with their pale, initial color, and excellent color retention. These finishes have equal or better perspiration resistance, alkali and alcohol resistance, and may be used on either open or closed grain wood. They may be sanded and polished just as easily as the conventional finishing type material being presently used.

We previously mentioned in this talk the possibility of adapting the room-temperature curing Epon resins with amines, as being adaptable for floor or furniture finishing. We feel that there are definite possibilities in this regard. The finish may be applied at 50 to 60 percent solids and may be handled within an hour. Heat will hasten the cure considerably. If no heat is applied, it will take 24 hours before this system may be walked on or is sufficiently hard for packing and crating. If one to two mils are applied, the coating may be walked on after overnight drying. If this finish is applied by spray to furniture, it may be dried in an hour at 110-120° F. Drying above 130° F. is not recommended, since the amine will be "flashed out" of the finish before it has a chance to react. Finishes thus applied exhibit unusual resistance to cold check; for instance, 25 cycles from 180° F. down to -60° F. without the slightest tendency to show any breakage or shrinkage of the film. The cured films also exhibit excellent rubbing and polishing properties, excellent gloss and depth of finish, excellent chemical resistance, perspiration resistance, together with the unusual adhesion and flexibility you always get with an Epon resin system. We feel that this is truly the finish of the future. There are some application drawbacks, but these are only mechanical in nature and, before too long, we are sure that difficulties of this type can be eliminated.

PROSPECTIVE FUTURE USES IN THE FOREST PRODUCTS INDUSTRY

In addition to the previously mentioned uses, investigations are being conducted to determine the suitability of Epon resin formulations for such things as a tempering medium for hardboard, to give a hard, tough, durable finish; as a coating for plywood-concrete forms where the excellent alkali resistance, toughness, and abrasion resistance of an Epon coating would be very beneficial; and for several other general purpose and specialty applications.

5. Film Forming Properties and Applications of Vinyl and Acrylic Resins[1]

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VINYL RESINS

The general class of vinyl resins includes: (1) vinyl chloride, (2) vinyl acetate, and (3) vinyl chloride-acetate co-polymers.

Solutions of Vinyl Chloride and Vinyl Chloride-acetate Co-polymers

Surface coatings based on solutions of vinyl chloride and the chloride-acetate co-polymers, when correctly formulated, yield finishes of unusual toughness, gloss, adhesion, and chemical resistance. They may be applied to a wide variety of surfaces such as metal, wood, cloth, paper, and concrete by any of the conventional methods of application. These vinyl finishes are noted for their resistance to the corrosive action of chemicals, fumes, and salt water, and are finding ever increasing applications in maintenance, manufacturing, and construction projects.

These finishes are prepared by dissolving the resins in organic solvents such as mixtures of ketones and aromatic hydrocarbons. They may be modified with a wide variety of pigments dyes, and plasticizers, as desired, but they show limited compatability with drying and nondrying oils, alkyds, phenolics, natural resins, or cellulose esters.

Surface coatings based on these resins dry solely by the evaporation of the solvent. Both air drying and baking types of finishes can be produced.

Certain of the vinyl coatings have been approved for direct contact with foods and have been used with excellent success to combat corrosion conditions encountered in dairies, breweries, and food packing industries to mention a few examples.

When properly applied, vinyl coatings give a completely continuous film and have been used successfully in the protection of wooden milk bottle cases, sorting tables in the fruit industry, milking stalls, laboratory tables, fish piers and wharfs, and other structures and commodities of wood.

Other solution formulations based on vinyl resins produce a vinyl lacquer which deposits a removable protective coating that can be stripped from the object coated.

Polyvinyl Acetate Solutions

Vinyl acetate resins are available as dry, granular powders that can be dissolved in solvents. However, by judicious control of the variables governing the polymerization process, it is possible to prepare polymeric vinyl acetate in solution at molecular weights comparable to the solid polyvinyl acetates. In this way, power and labor for grinding and dissolving are eliminated. Also, manufacturing costs are reduced by avoiding the stages of isolation and drying the polymers. These savings are passed on to the consumer.

Polyvinyl acetate resin is characterized by extreme clarity and stability in the presence of heat and light. It is odorless, tasteless, colorless, and non-toxic. Solutions are unaffected by inorganic salt solutions, dilute alkalis and acids. Because of their excellent physical and chemical properties, polyvinyl acetate solutions have found widespread use as adhesives, surface coatings, and saturants.

The remarkable adhesive qualities of polyvinyl acetate have led to the adoption of this resin for binding a multitude of materials including wood, glass, paper, leather, metals, metal foils, textiles, stone, mica, ceramics, cardboard, cellophane, cellulose acetate, and other plastic materials.

In the food packaging industry vinyl acetate solutions or hot melts have assumed considerable importance as paper coatings. The dried coatings are free of color, taste, and odor, and are greaseproof. Also, these coatings are heat sealable. In some cases the acetate coating fulfills a bifunctional need whereby a single coating operation provides both grease resistance and a means of rapidly heat sealing the coated container.

The acetate resin is compatible with many other resins and gums and combinations are readily made. Some of these are phenolics, nitrocellulose, chlorinated rubber and paraffins, rosin, Dammar, Vinsol, and some of the acrylics.

Emulsions or Water Dispersions

When referring to resins and plastics, these terms are often used interchangeably. However, for the purposes of this discussion,

[1] Presented at meeting of Forest Products Research Society, Pacific Northwest Section, Portland, Oregon, May 20, 1952.

the term dispersion will be used, since we are not dealing with the conventional water-in-oil or oil-in-water emulsion, but rather with an actual dispersion of extremely fine particles of resin in water, produced by the actual polymerization of the monomer in water. The particle size and charge can be controlled by the conditions of polymerization and choice of emulsifier.

Water dispersions have several advantages over solutions. In coating, where a high "build" is desirable, low viscosities and high solids are essential. Generally, it is possible to obtain higher solids concentrations at workable viscosities through the use of dispersions of high molecular weight polymers than with solvent solutions of the same polymers.

Through the use of aqueous dispersions, porous surfaces can be uniformly coated with controllable film thicknesses. The aqueous portion of the dispersion can be made to penetrate into the surface leaving the resin phase on top, or, for improved bonding, penetration can be increased.

A particular advantage of dispersions is the ease with which they may be applied to damp or wet surfaces to which ordinary lacquers or paints will not adhere. Emulsion paints have a distinct advantage over oil paints for coating plaster, masonry, or damp wood.

Fire and explosion hazards are practically eliminated when dispersions are used for coating, laminating, or saturating in place of resin or lacquer solutions. Also, problems of toxicity and odor are eliminated.

Dispersions have several potential disadvantages. Films cast from dispersions are impure due to the emulsifiers and protective colloids present. They tend to give cloudier, less homogenous deposits which are less waterproof and water resistant than the corresponding polymer solutions. Many of these difficulties can be overcome by proper treatment or compounding of the dispersions.

A typical vinyl chloride copolymer dispersion has a solids content of 45 percent with a viscosity of only 10 to 20 centipoises. The air dried film is clear, glossy, flexible, and extensible. It contains no added plasticizers and is, therefore, free of the disadvantages of embrittlement and variable film properties due to plasticizer migration or volatilization.

This dispersion can be diluted infinitely with water and is stable at all practical concentrations. It has excellent mechanical stability and is stable to the addition of aqueous solutions of salts. It is compatible with a wide variety of pigments and can be thickened with many of the conventional thickening agents.

The film of this material has excellent water and grease resistance and has good heat sealing properties. It is non-blocking and has excellent solvent resistance to alcohol and paraffin hydrocarbons.

One of the most versatile of the water dispersions commercially available is vinyl acetate emulsion or dispersion. Vinyl acetate dispersions are available in a wide range of physical properties. Solids content of over 60 percent can be produced. Viscosity ranges from 800 cps. to over 30,000 cps. with particle size of less than 1/2 micron to 10 microns are available.

The vinyl acetate dispersions produce films having substantially the same chemical and physical properties as those produced from the solvent solution except with the limitations inherent in water dispersions.

Vinyl acetate dispersions are compatible with a wide range of starches, pigments, plasticizers and resins. When suitably compounded, they are widely used as paper adhesives, wood glues, paper coatings and binders for all types of materials. One of the latest developments is the use of vinyl acetate dispersion in concrete. Tests have shown that concrete having many times the strength of conventional concrete can be produced in this manner.

The excellent adhesion and high pigment binding properties of vinyl acetate dispersions together with the excellent properties of the film such as clarity, light fastness, and resistance to yellowing and embrittlement with age makes vinyl acetate dispersions an excellent starting point for the formulation of water based paints. Certain limitations which have existed are being overcome and today specialty protective coatings and paints based on vinyl acetate dispersions are being produced. It is felt that such coatings and paints will play an increasing role in the water based paint picture.

ACRYLICS

The acrylic resins are polymers of derivatives of acrylic acid. The characteristics of the polymers depend to a large extent upon the chemical constitution of the monomeric forms although polymerization conditions also have considerable influence. Resin polymers varying from hard and glassy to soft and rubbery are produced. The acrylics are noted for their crystal clarity,

heat and light stability, gloss, and chemical resistance.

Solutions

Acrylic solutions find acceptance as crystal clear, glossy, nonoxidizing coatings and as bases for compounding adhesives. Various degrees of flexibility can be obtained.

Acrylics are compatible with nitrocellulose, chlorinated rubber, and vinyl resins, and have limited compatibility with other cellulose resins. Drying oils and oleoresinous varnishes are not compatible with the acrylics. A wide variety of solvents may be used as thinners to adjust the drying characteristics including such solvents as coal tar hydrocarbons, chlorinated hydrocarbons, ketones, and esters.

White enamels based on specific acrylic solutions will withstand high temperatures and have excellent color retention. These enamels can be made both air drying and baking and are resistant to chemical acids, alkalis, etc.

Emulsions or Dispersions

Special polymerizing conditions result in the formation of high solids water-thin emulsions with a dispersed resin phase having an extremely small and uniform particle size. This assures excellent stability, long shelf life, and good spraying and dipping qualities.

A wide range of film properties can be obtained by modification of the type and amounts of the copolymer ingredients. Clear, transparent films ranging from hard and tough to soft and rubber like are deposited from these dispersions. Use of minimum amounts of water-soluble emulsifiers insures excellent water resistant qualities in the dried films. Due to the nature of the copolymers used, the acrylic copolymers can be considered internally plasticized and in most applications, additional plasticizer is not required.

The acrylic water dispersions have high binding power for clays and pigments and are of particular value as greaseproof and abrasion resistant coatings for the paper, textile, paint, and leather industries.

Certain of the acrylic emulsions have shown unusual promise as bases for all plastic floor coatings in place of the usual wax emulsions. The products, when properly compounded, form clear tough abrasion-and slip-resistant floor finishes. They also show excellent unbuffed gloss and good leveling characteristics on linoleum, rubber composition tile, wood, and hardboard. They possess water resistance and second coating properties, and have excellent shelf life.

6. Discussion[1]

QUESTION: What is the basis of this new line of phenomenal exterior paints that the manufacturer says is good for one coat every fifteen years?

PANEL MEMBER: It is a heavy, textured coat for exterior applications. The first one was an alkyd resin based on a Navy specification, 52P62, then a shift was made to using vermiculite filler. The next step was to emulsify the finish. Pabco had one for a short time but withdrew it from the market because of undue claims made by applicators. In the composition of these textured paints, most of them are alkyd resins heavily filled with vermiculite or other inerts.

QUESTION: How successful are those paints?

PANEL MEMBER: They have not been in use long enough to determine the success of the coating.

QUESTION: We have a lot of lumber products that go into exterior use where they require a clear finish. I would like to get an idea of the relative film-forming abilities of the several products.

PANEL MEMBER: It depends on whether you want actual durable characteristics without regard to expense or an economical film, which is quite a different thing. Co-polymer resins have very poor durability on wood so they should not be used. We had a wide range of co-polymer resins on the market and none of them are nearly as good as the long-oil, pure phenolics or alkyds. Perhaps the pentaerythritol type alkyd with mica as a flatting agent is most successful. The service life of this type of paint is about the same on wood and metal. The life on metal of the co-polymer type finish was comparable to the medium length oil. There was little to choose between the pure phenolic resin and the glycerine type of alkyd resin except that the phenolic resin discolored more. The biggest improvement was made by adding an inert pigment such as ground mica, Santocel, etc. These double the life of the coating. Generally, the type of failures of pure phenolics is the tendency to fail by loss of gloss. Long oil alkyds will fail by cracking. Films without elasticity tend to crack and check on exposed wood and then the whole film is shot. To date, exposure tests of the linseed oil modified Epon ester show that they will perform as well as the tung phenolic on fir and pine. It looks good to date after a three-year exposure. Polyester type is rather difficult and expensive to apply. The tendency to "alligator" can be overcome by applying a thick film and sanding. The successful polyester coating requires more experience to apply than the other coatings. It is expensive but will last a terrifically long time.

QUESTION: How much effect does the water in a latex emulsion have in swelling the wood on which it is applied?

MR. GENTES: The water content of the average latex emulsion is about 50 to 55 percent. This could have a slight effect on the wood. The amount of this water absorbed into the wood depends on the porosity of the surface. On low density products, there is considerable absorption; on glass, there would be none.

QUESTION: Can you repaint over latex paint?

MR. GENTES: In general, yes. They are often used as a first sealer under conventional paints.

QUESTION: Is it a good vapor barrier when it is dry?

MR. GENTES: Yes, it is. In fact, a special latex preparation is being sold for this purpose.

QUESTION: How complete a film is formed as the latex particles coalesce on drying?

MR. GENTES: That depends on the latex. Some particular ones are very hard and you have to add a plasticizer or heat; some are soft and will form a continuous film upon air drying.

QUESTION: How does the adhesion of latex compare with regular oil-base paints?

MR. GENTES: When first set, the latex paints tend to be water sensitive. Styrene-butadiene resins do change chemically on drying, thus adhesion is improved. Water emulsion paints are incompatible with oil or grease con-

[1]Pertains to foregoing papers presented at meeting of Forest Products Research Society, Pacific Northwest Section, Portland, Oregon, May 20, 1952.

taminated surfaces.

QUESTION: Do the methyl cellulose sealers wash off when latex emulsions are applied over them?

MR. GENTES: Methyl cellulose sealers would probably work satisfactorily under latex coatings since they are somewhat water resistant and the latex paints dry rapidly.

QUESTION: How do the film forming materials discussed in the panel fit into wood finishing?

DR. BROWNE: For wood, the major interest lies in the drying oils, the alkyd resins and the phenolic resins. Drying oils and modified drying oils have been widely used for a very long time in both clear and pigmented coatings for wood. Alkyd resins are widely used in interior and exterior enamels, in trim and trellis enamels, and in clear varnishes. Phenolic resins are used in fast drying varnishes and enamels and in highly water-resistant clear finishes.

In connection with the question about natural finishes for exterior surfaces, I find that the puolic asks most often for a finish that will retain as nearly as possible the appearance of the lumber as it comes from the lumber yard. The wood sealer finish comes nearest to satisfying that demand. Varnish is seldom advisable for two reasons: (1) Varnish fails to give the appearance the public wants, and (2) after a few renewals varnish usually cracks or flakes so badly that the entire coating must be removed before refinishing.

JOURNAL of the FOREST PRODUCTS RESEARCH SOCIETY

Furniture Finishing in Southern California[1]

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INTRODUCTION

Certainly not the least among the industries which have exhibited such phenomenal growth in the Southwest during the past decade, is the production of household furniture. According to figures furnished by the Furniture Manufacturers Association of Southern California the annual production averages a total dollar production of some $180,000,000. Los Angeles County represents geographically an area which contains a greater concentration of furniture production than any area of comparable size in the world.

In this area, there are manufacturers of every size and description, numbering about 550, and producing almost every type of furniture sold.

Southern California has long been recognized as the country's leader in the styling of modern and casual furniture but their real leadership is more probably in the recognition of the importance of color and its astute application. It is only natural that an area of the country where casual, informal living is stressed should originate this characteristic styling which has now been so widely accepted.

In spite of the "resort" climatic conditions characteristic of this area, many problems have presented themselves to the producer of furniture. Superficially it would seem that such climatic conditions would represent an ideal set of circumstances for the production and finishing of furniture. Such is far from truth, however, and until these factors were recognized the market for furniture manufactured here was limited to the immediately surrounding area and such pioneering manufacturers as attempted to extend their distribution were met with discouraging and costly experiences in the form of furniture arriving at it's destination with the finish badly checked or off color because of severely "grayed" filler and improper staining.

In more recent years, the production of television and radio cabinets has contributed a considerable percentage of the total furniture produced in this area. Since, in many cases, this entailed the nation-wide distribution of cabinets manufactured in the Southwest, manufacturers first became aware that perhaps conditions attendant on the finishing of wood in this area offered problems which may not have been widely encountered in other locations.

Until recent years, the local industry was serviced largely by local finish manufacturers with largely local experience. While the finishes and finishing techniques developed were quite adequate for local purposes they did not provide for conditions encountered in national distribution.

Since the furniture manufacturing center that had mushroomed in this area, was the newest in the country, it was only natural that the newer methods developed and tried by the industry in older areas should be rather widely adopted. Automatic equipment was installed freely and a high percentage of the plants installed conveyorized finishing systems, many with force drying ovens.

It was not only the recency of the industry, however, which prompted the widespread adoption of moderan production and finishing methods. While Southern California represented a good area both from the viewpoint of a local market and available man-power, it was totally devoid of any usable raw material in the form of wood. Even the great forests of the adjacent Northwest offered only a limited selection of woods which were acceptable to the local furniture manufacturer, and these had to be transported over relatively long distances to be employed in the southwestern production. Most of the popular hardwoods had to be imported from the east.

To complicate the situation further, machines tools, screws, hardware and virtually everything that went into the production of furniture had to come from the East. As a result, the southwest experienced the highest raw-material prices of any producing area. For perhaps a brief time the industry enjoyed a relatively low labor cost but general industrial growth and expansion in the area made this situation very short lived.

With the pressure of these circumstances the industry naturally turned to the only logical solution: high-speed, mechanized production. As a result, the furniture plant on the West

[1] Presented at meeting of Forest Products Research Society, Pacific Southwest Section April 23, 1952.

Coast which does not employ conveyorized finishing is the exception rather than the rule.

With the area exhibiting phenomenal industrial growth it was only natural that industrial real estate should skyrocket in value, thus presenting to the growing furniture industry a very definite economic expansion problem. Frequent deliveries of raw material (lumber) could solve the problem of storage space at the front end of the operation but plant space was simply not available to provide long drying times of finishes on the expanded production schedules. Heat tunnels to force the drying of coatings were installed on the conveyor lines and the vendors of finishing materials were being pressed for ever faster drying finishes.

These formulations were probably largely directed toward the inclusion of relatively high percentages of the types of hard resins which would exhibit fast solvent release and contribute a very fast initial hardening of the film.

LOCAL FINISHING DIFFICULTIES AND THEIR CAUSES

While such materials certainly worked well on the finish line they often exhibited an early break-down in the field -- a factor which was certainly not inconsequential in the early reputation which characterized much of California furniture as being of low quality. Manufacturers who were expanding their sales beyond the immediately surrounding area would also occasionally experience the arrival of a car or truck load of furniture at it's destination exhibiting either slight or very severe checking of the finish. This checking was apparent as very fine cracks in the finish that usually were not noticeable on the surface but which appeared as very fine light lines when struck by oblique strong light. In the case of solid woods the checks usually appeared in straight lines at right angles to the direction of the grain of the wood. On veneer surfaces the checks would rarely run in straight lines and were usually in a direction oblique to the direction of the grain of the wood.

These checking conditions were usually encountered in the wintertime when, although the conditions within the production area were fairly temperate, subzero temperatures were existent in the mountain passes through which the finished furniture must be shipped. The finishes formulated to accomodate the very high speed production schedules were, at that time, sadly lacking in the flexibility and resistance to thermal shock required to withstand such exposures.

As the result of various contributing factors, the industry was faced with an acute shortage of high-quality, well-cured furniture woods. Because of this condition much wood, which pre-war would have been considered unfit for furniture use, found its way into regular production. Woods of poor texture and appearance were often sold at premium prices because of the acute scarcity. The effect on the West Coast was particularly bad because, too often, wood shipped here represented what was "left over" after the eastern "on the spot" purchasers had selected the better portions. Many western furniture manufacturers are of the opinion that this condition still exists and probably always will.

Let us first consider the influence of climatic factors on finishing in this area. It is the writer's opinion that this represents probably the greatest single factor that must be dealt with in the successful local application of high-quality finishes.

Because of the prevailing climate, very few industrial plants in this area have any provisions for heating the production sections of their plants. This means that finishing room conditions substantially reflect local weather conditions. When it's hot, the finishing room is hot; when it' cold the finishing room is cold; when it's dry, the finishing room is dry; and when it's wet, the finishing room is damp.

Since the area's annual rainfall is relatively slight and concentrated in only a few months of the year, the provisions for protected storage of lumber are nowhere near as elaborate as in the average eastern plant. As a result the stock probably shows a much wider variation in moisture content than would be experienced elsewhere, being abnormally high in winter and abnormally low in summer.

Oddly enough, however, this change in total moisture content (which naturally takes place at a very slow rate) does not seem to be a major factor affecting the performance of surface coatings.

Of much greater significance is the absorbed surface moisture which varies greatly according to the completeness of protection and stability of conditions provided by the individual plants. Since adequate control of these factors would be unreasonably costly a very simple compensating mechanism has been developed which produces eminently satisfactory results. This mechanism will be discussed at length later.

This surface moisture will vary over a quite considerable range, during periods of dry weather, without apparently affecting readings taken to determine total moisture content of the wood.

A standard type of moisture meter is used with a smooth flat disc substituted for the needles used in making average moisture content determinations. Readings obtained in this manner will sometimes show a very substantial variation between readings taken at 8:00 A.M. and readings on the same piece of wood taken at 3:00 P.M. of the same day.

The phenomenon is not particularly hard to account for. During the "dry" period in Southern California the changes in temperature and absolute humidity are very wide and rapid. It is not unusual, within the city area, to experience days when the temperature is up to 90° (and the relative humidity down to 40), and within a relatively short time after sundown the temperature is in the high 60's and substantial deposits of moisture are forming on all exposed areas. A heavy dew is the rule rather than the exception here.

This wide and rapid change in temperature accounts for the large range observed in measured adsorbed surface moisture.

Another manifestation of this effect has been repeatedly noted by observing the surface appearance of stock on the finishing line. Freshly sanded stock, which has been well prepared to receive the finish by final polishing with a 6-0 paper, exhibits a rather high angular sheen. When viewed from a few degrees above, or parallel to the surface, the wood appears to have a high gloss, particularly when viewed in the direction of the grain.

If immediately finished, this piece will accept the properly formulated finishing system with very gratifying results. If, however, this case is allowed to stand overnight, or worse still, over the week-end in the average Southern California furniture plant, it will lose the appearance of high angular sheen and actually feel quite rough when compared to a freshly polished (sanded) piece of wood.

What has happened is that the freshly exposed wood cells have absorbed sufficient of the surface adsorbed moisture to swell and give the polished surface a "rough" appearance and "feel".

The situation is, of course, not so serious in cases which have only stood over night as is with objects which have been allowed to stand over a week-end. It is also not so noticeable in freshly laid-up veneer stock as in stock that has been in storage for some time.

This fact is also of particular significance to the furniture manufacturer in the Southwest. There are many furniture manufacturers in this area who import dimension stock. Unquestionably this practice permits the user to realize considerable economy particularly when he has a source of supply that provides him with good quality stock from which there are few culls. However, this same meterological phenomenon is at work on the dimension stock all of the time it is in storage.

We have frequently encountered situations where the inability of a case to accept a good finish was traceable directly to how far down in the pile a particular panel of this type was stored. The first 10 or 20 panels are prone to show an over-all malperfomrance with respect to applied finishing systems while those farther down in the stock are apt to show the same tendency only around the edges with the center portion of the stock offering no finishing difficulties.

I am sure many furniture producers have, from time to time, experienced this rather puzzling occurrence in this area.

The degree of trouble encountered is in direct proportion to how long the stock has been stored and proximity of the manufacturing plant to the coastal areas. Normally more trouble is also to be expected during the winter months than in summer.

In the case of freshly laid-up veneer, the heat produced in the final "polish" sanding of the case is sufficient to adequately drive out this moisture so that if the case goes from the final sanding operation to the finishing room within a reasonable length of time it will readily accept a good finishing system with a minimum of difficulty. Dimension stock, on the other hand, which has been stored for some time under the normally adverse conditions usually encountered in this area, will often not be completely restored to a "finishable" condition by the sanding operation above.

There are two principal finishing defects that characterize the manifestation of this surface moisture adsorption phenomenon. The first, and certainly the most common and bothersome is blistering.

In appearance, this blistering is the same as that encountered when using lacquers or varnishes with improperly formulated solvent

blends. In occurrence, however, there are usually two important differences that distinguish this type of blistering. First, it is not consistent, that is, it does not appear to the same extent at all times. It is most likely to appear with greater severity on cases which have stood for some time, after final sanding, prior to finishing. For example, cases that received their final sanding late on a Friday afternoon and were placed on the finish line on Monday morning. As the week progresses and fresher cases reach the finish room the blistering becomes less extensive and usually disappears entirely in plants where there is a reasonably fast movement of work.

Second where the case is made up of a combination of "porous" veneer or solid stock such as mahogany, walnut, oak, etc. and close grained hardwood such as gum, maple, alder, etc., (on rails, stiles, end-pieces, etc.), the blistering is apt to be totally absent on the close-grained hardwood but quite evident on the "porous" hardwood.

The blistering usually occurrs at the point in the system where the first coat of material of appreciable solids content is applied. This will normally be the sealer coat. The blisters appear very quickly while the coating is still wet and, with proper illumination, they can be observed forming at the wood-coating interface. They appear as very small air bubbles in the wet film but do not rise to the surface and break as is characteristic in the case of the occluded air which becomes mixed with the finish while it is being atomized in the spray gun.

When the sealer is sanded the blisters are cut through and become filled with sanding dust at which point they are quite evident. Upon the application of the successive top coats additional blisters form wherever they had been cut through during the sealer sanding operation.

In very severe instances the finish cannot be rubbed without opening many of the blisters and producing a finely pock-marked appearance on the surface. In cases of lesser severity the blisters appear as tiny bubbles that seem to be "floating" in the film. Obviously, the greater the clarity of the finish system involved, the more obvious the defect becomes.

The second finish defect which may be caused by adsorbed surface moisture is "graying" of the filler and is characterized by the filler in the pore gradually turning to a light color so that the pore areas instead of appearing dark will be actually lighter in color than the surrounding area. It is particularly obnoxious when it occurs in fairly dark, brilliant mahogany or walnut finishes.

In severe cases the "grayness" may extend over the entire finished area so that the object has an overall dull gray cast instead of the normal brilliant, clear color.

This "graying" defect follows the same behavior pattern as described for the blistering defect and should not be confused with the "graying" of the filler which is so commonly encountered with finishing systems which are improperly formulated or which are not adaptable to many Southern California production schedules.

As the result of a comprehensive study of these phenomena, a relatively simple solution to the problems that arise as the result of adsorbed surface moisture has been devised. The solution consists of installing a bank of infra-red heat lamps at the beginning of the finish line through which the cabinets pass just prior to the start of the application of the finishing system.

One such installation, which has been in successful operation in this area for about two years, is illustrated. (Figure 1)

It has been determined that the lamps should be arranged so as to produce a wood surface temperature of about 90° F. In the case of conveyorized systems, an automatic cut-off switch should be installed so that stopping of the conveyor will not cause scorching of the wood.

Convection heating of the wood seems to be very ineffectual in the removal of surface moisture. Twenty seconds of infra-red heat have repeatedly produced results superior to 2 hours of heating in a convection oven.

In addition to the climatic considerations which must be understood to produce good furniture finishes in this area, the finishing materials themselves must be so formulated as to be applicable to high speed production and still give maximum appearance and durability characteristics.

Let us consider the finishing materials in the order that they would appear in a normal finishing operation.

FINISH COMPONENTS AND THEIR APPLICATION

Stains

Furniture woods are almost never finished in their natural state. Color is imparted to the work either to enhance the natural color of the wood, to comply with the consumers idea of what "maple" should look like, to change the character of the wood completely (such as blond oak), or to serve the purpose of minimizing wood defects and inconsistencies of color.

For conventional finishes, most plants use the standard "non-grain-raising" stains. These consist of water-soluble dye powders dissolved in a solvent combination which will tolerate a reasonable concentration of color but which will not cause excessive swelling of the surface wood fibers as water does. This type of stain is familiar to all wood finishers and needs no discussion here except to suggest that in plants where excessive moisture conditions are particularly adverse, blistering of subsequently applied top coats may often be avoided by the infra-red drying of these stains. (Figure 2)

Wiping stains, while exhibiting excellent "uniforming" qualities and some "filling" ability, are usually not applicable to high speed finishing systems because of the normally long drying time necessary before recoating. The extra labor involved in the wiping operation also often makes their use prohibitive. In a properly formulated system of finishes, however, wiping stains have been used successfully in fast systems in this area.

Of particular interest for our consideration here are the newer pigmented "ground-coat" stains. These usually consists of carefully selected types of "clear" pigments of good color stability, finely dispersed in either a nitro-cellulose lacquer or synthetic resin base. For purposes of stability and control, the nitrocellulose types are usually supplied to take very large reductions for use. Reductions run in the range of from 5:1 to 20:1. The synthetic types are sometimes sold ready for application but for good package stability they should be supplied in a more concentrated form.

Properly formulated stains of this nature produce finishes of remarkable clarity and have excellent uniforming characteristics since they are not selectively absorbed by woods of varying density or porousity.

They are not particularly adaptable to dark colors such as mahogany but produce excellent results in colors such as maple, Early American, Provencal, light walnut, etc. They give particularly good results in the newer "accent" finishes where it is desirable to accentuate the pore and grain structure of relatively nonporous hardwoods such as birch.

Their application characteristics are excellent and "professional looking" staining can be accomplished by inexperienced spray personnel because of their lack of a tendency to build up color value as a result of overlapping spray which so often occurrs with conventional "non-grain-raising" stain.

One word of caution, however, is in order. Be sure that your supplier is experienced in the production of this type of stain. The selection of pigments used in these stains is the difference between good and bad results. Also, the control in manufacture is not nearly as simple as with the "non-grain-raising" types or wiping stain.

Outstanding results have been obtained with these "ground coat" types of stains when used in a system that also includes glaze.

This type of stain is completely non-grain-raising and the lacquer types require no drying time when used in a lacquer system.

Several West Coast furniture manufacturers have been successfully using these stains for several years and report color stability superior to the "non-grain-raising" types.

Although not strictly in the category of stains, pigmented base coats should be discussed here because they are normally used in place of a stain. These are coatings of fairly high pigmentation used to nearly obliterate the grain pattern of the wood. The character of the wood is then restored by filling the pore with a filler of contrasting color.

They are very popular in the production of blonde finishes on oak and Philippine and Honduras mahoganies.

In high speed finishing systems this type of coating has almost completely replaced bleaching of the woods with hydrogen peroxide.

The danger to be guarded against in this type of coating is the use of either too high or too low a pigment-vehicle ratio. When the pigment-to-vehicle ratio is too low the coating will too completely fill the wood pores and will not permit a proper filling operation. This results in a very "painted" appearance because the character of the wood is not apparent. When the pigment-to-vehicle ratio is too high

the coating may produce a finish that will either "wipe through" during the filling operation or may produce a final finish with a tendency to peel off.

These coating should only be applied to well sanded stock because the pigment has a tendency to collect around wood fibers that stand up from the surface, and produce a "mottled" appearance.

Improperly formulated solvent blends in these coating will also produce a similar effect.

Fillers

To understand thoroughly the local problems involved, it is first necessary to establish those qualities of composition and performance that are characteristic of a good filler.

First, as the term implies, the product should have good filling properties. To realize this it is necessary that the compound be used at nearly 100 percent total solids. While it is true that fillers are conventionally applied at much lower solids, they are always permitted to "flash off" before padding and wiping. This means that the solvent used to make the application easier (either by spray or brush) has substantially evaporated, leaving the filler more or less in its original package condition. The mechanics of filling takes place when the filler is padded into the pores and the excess removed by wiping. It is at this point that the filling compound should be at substantially 100 percent solids since the subsequent removal of any appreciable amount of solvent (which also occupies volume) would result in excessive shrinkage of the compound left in the pores. The net result is poor filling, which produces an "open" or "skinny" finish.

The ideal binder, then, for a wood filler would be a vehicle that would have very low viscosity characteristics at 100 percent solids, would dry rapidly, have good shearing characteristics (not "sticky") and would be compatible with any materials that might be used for recoating.

Unfortunately, such a liquid does not exist.

From the viewpoint of filling and wiping qualities raw linseed oil is an ideal filler vehicle -- it has low viscosity at 100 percent solids and good shearing and wiping characteristics. It is, however, a very slow drying material that cannot be recoated for about 24 hours and the dried film has very limited compatibilities especially with lacquer type materials. Once recoated the oxidation of the oil is also greatly retarded so that maximum adhesion is not obtained until after several months drying.

Polymerizing the oil by heat bodying or blowing improves its drying and compatibility but also increases its viscosity so that adequate amounts of binder cannot be included in a workable product. With all it's shortcomings, however, linseed oil was considered for years as the only really satisfactory vehicle for wood fillers and is still used to an appreciable extent.

Synthetic resins such as an oil-modified glycerol-phthalate resin would constitute an ideal filler vehicle from the viewpoint of speed of drying, adhesion and compatibility but their viscosity characteristics are too high and their shearing and wiping qualities too low.

About 15 years ago the so-called 4-hour fillers became very popular. They represented a compromise between the slow drying straight linseed oil types and the unworkable "alkyd" type of filler. They were hailed by the industry as a great boon to the furniture finisher because now, for the first time, fillers and top coats could be applied in the same day. But even force drying the fillers at temperatures which would not harm the woods and veneers still required a minimum of 2 hours drying.

While these fillers represented considerable progress from the drying time viewpoint, compromises had been made and the ultimate adhesion characteristics left very much to be desired and they were still not fast enough for the streamlined finishing systems that were being required in the Southwest.

Another limitation of the 4-hour type of filler is it's tendency to absorb the metal-salt catalysts present as "driers". Stocks of these items should be carefully rotated so that filler in excess of 6 months age is never used in production operations unless the full complement of driers used in original production is added. Indeed, for optimum results, all stocks of finishing materials should be rotated so that they do not become excessively old before use.

As a solution the so-called 1-hour fillers were developed which had quick recoatability but usually had poor wiping and filling characteristics and even poorer ultimate adhesion. Their binder composition usually consisted of a low viscosity lacquer-plasticizer type of oil fortified with a small amount of hard resin such as ester gum or hard maleic resin. They were recoatable only with lacquer type materials,

the non-drying oils or plasticizers involved causing either complete non-drying or hyper-soft films when recoated with synthetic or "varnish" type top coats.

Until recent years the industry accepted as more or less inevitable the fact that finishes applied over wood that required filling would exhibit relatively poor adhesion characteristics as compared to the same finishes applied on bare wood.

At about the beginning of World War II research had begun which indicated a solution to the dilemma of good adherence of finishes over filled surfaces. The completion of this work was considerably delayed by the war years. When research projects and raw material availability returned to normal the project was completed and offered what seems to be a very obvious answer to the problem: supply the proper binder to the filler after it has been applied!

While this answer in retrospect seems obvious, the development of such a mechanism is looked upon as one of the most outstanding accomplishments in the history of wood finishing.

This system has made possible the recoating of a good filling operation in as short an air-dry time as 2 hours and has given consistently good results on force dry systems as short as 25 minutes at 135° F.

In addition to considerably shortening dry periods, this system has greatly improved the adhesion characteristics of finish systems involving filler. It has improved the clarity and depth of these finish systems and has considerably enhanced the durability both from the viewpoint of cold checking and veneer checking.

It offers to manufacturers in this area the possibility of producing, on limited drying schedules, high quality finishes of excellent appearance and durability.

The mechanism is very simple. It consists of application of filler in the normal manner, followed by application of the "binder" coat immediately after wiping, before the filler in the pore has had a chance to set. The material is applied in a thin "mist" coat -- never a full wet coat. This controls the degree of penetration into the filler so that a portion of the "binder" coat remains on the surface where it contributes materially to the "hold-out" or fullness of the subsequently applied coatings.

Properly formulated coatings of this type exhibit much less tendency to swell the underlying wood fibers than do conventional lacquer sealers which also contributes to a smoother ultimate finish with much less expenditure of mechanical effort.

Sealers and Top Coats

Very little additional discussion relative to sealers and top coats is called for in a discussion of this nature except the caution relative to adverse durability and performance characteristics of coatings that dry too fast. Nothing beyond the hardness of film that will permit packing should ever be required of the film in the furniture manufacturers plant. Too often the manufacturer judges his finish by digging his finger nail into a system that is only a day or two old and decides that a certain finish is too soft or "cheesy" with no consideration as to the ultimate durability of such a film. Realistically, the hardness of finishes should be judged based on a drying time equivalent to the length of time that will actually elapse before the article is placed in actual service. This is usually a period of at least a month. Any finish that will withstand a standard "print test" of one pound per square inch (at 100° F.) will survive the rigors of packing and shipping unless the shipping containers are very poorly designed.

Perhaps one other word of caution is in order relative to top coats. It is especially necessary that all coatings be adequately dried in a system where mixed types of compositions are employed. By this, I refer to a system employing, for example, a lacquer type sanding sealer that is recoated with a "synthetic" type of top coat. This top coat could be either conventional synthetic varnish, and alkyd-urea heat-converting varnish or a catalyzed alkyd-urea, air dry coating.

If such a system is applied on too fast a schedule and the lacquer solvents are not sufficiently removed from the sealer coat before the synthetic top coat is applied a severe type of checking, referred to as "alligatoring", will develop. The term "alligatoring" is employed because the checking very often follows a pattern resembling the design of alligator skin. The checking will occur after a lapse of any time from 24 hours to several months, depending upon the degree of solvent retention in the sealer film.

The ease with which the sealer will sand is no criterion of the "dryness" of the sealer because large amounts of stearate soaps in the sealer will give the appearance of good sanding while considerable amounts of solvents are

still retained in the film.

The wise furniture manufacturer will base his selection of finishing materials upon adequate qualification tests that will give him a complete picture of performance and durability.

SPECIFICATIONS NEEDED

Certainly in an area where this industry is so large and concentrated there should exist specifications that would adequately cover the performance and durability characteristics of finishing materials required by the industry. It would seem to me that it would be a very worthwhile project for this organization to compile such a set of local finish specifications.

Figure 1 -- Infra-red pre-finish drying of television cabinets in a radio and television plant in Los Angeles.

Figure 2 -- Infra-red drying of non-grain-raising stain in a radio and television plant in Los Angeles. The drying unit can be seen on the right, installed about 10 feet away from the stain booth.

JOURNAL of the FOREST PRODUCTS RESEARCH SOCIETY

Bundling Pulpwood in Western Washington[1]

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INTRODUCTION

Several companies on the coast have been interested in the bundling of small logs and pulpwood for ease of handling and reducing log loss in water storage.

Among those companies which have had some experience in bundling are Crown Zellerbach, Schafer Logging Company and Publishers Paper Company. Most of the information available for this paper is from the experience of Rayonier Incorporated in strapping and bundling. Rayonier now has strapping and bundling operations at Willapa Harbor, Grays Harbor, Sekiu and Port Angeles. This paper will attempt to describe bundling operations at these various places.

Rayonier uses both pulpwood and logs in making pulp. For the purposes of this paper pulpwood shall be defined as wood measured in cubic content and logs shall be wood measured in board foot content. Most of the wood used by Rayonier is western hemlock with minor amounts of Sitka spruce and silver fir.

EQUIPMENT AND METHODS

For both pulpwood and logs Rayonier now uses 9/16-inch acid-resistant, wire cable straps approximately 30 feet in length. Special Meighan hooks are used as fasteners on the straps. Galvanized cable was originally used but it was found that the treated rust-resistant cable was just as satisfactory and it is considerably cheaper at present. Galvanized cable is also hard to get at this time. After three years some of the original rust resistant straps are still being used. Flat steel bands have been used for bundling but they have proven somewhat unsatisfactory for our purposes.

Pulpwood is strapped for temporary dry storage at the Rayonier Willapa Harbor reload station. The pulpwood is brought to the reload in 8-foot lengths, usually in three- to five-cord truck loads. The load is usually divided into two parts by separators in the woods. A crane is used to lift off the half load and a single strap is placed around the center of the bundle while it is being held by the crane after which the bundles are placed in a pile for temporary storage. This bundling is done in order to facilitate the handling of the pulpwood in loading railroad cars from storage. The straps are removed from the bundles after they are on the cars.

At the Rayonier Port Angeles plant, pulpwood is brought to the plant in uneven lengths of from 8 to 40 feet. This pulpwood is bundled into half loads in the woods with straps on each end of the load. In all of the Rayonier pulpwood bundling operations, the size of the bundle depends primarily on the capacity of the crane that is available to handle the wood. Some of this pulpwood at Port Angeles is put into the water and part of it is put in dry storage.

Rayonier is bundling small logs at one Grays Harbor log dump. The logs are strapped on the truck at the log dump with a strap on each end of the load about three feet from the end of the shortest log. The load is then lifted from the truck and slid into the water on a gentle incline. It is necessary to handle the bundles in this manner so that the fasteners on the bundles will remain on top to facilitate unhooking at the mill. Rougher handling of the bundles will also result in more broken straps.

Ordinarily, when small logs are handled individually in the water there is a large loss from sinkers, logs slipping out of rafts, and miscellaneous causes. This loss often amounts to as much as 5 percent or more of the total number of logs handled. These lost logs must be gathered up separately in a costly operation and many of them cannot be recovered at all. In 1950 Rayonier handled approximately 27,000 bundled logs at this log dump. Of the 27,000 logs only 32 logs were lost or could not be directly accounted for. In 1949 approximately 27,000 logs were handled with only 34 logs lost. Log average in 1949 was 317 board feet with a bundle average of 4,125 board feet.

At Rayonier's Sekiu log dump, logs are strapped on the company railroad cars and dumped into the water. The bundles are then put into crib rafts and towed to Port Angeles. After the breakdown of the rafts at Port Angeles, many of the bundles are floating with the fasteners under water. In order to facili-

[1]Paper presented at the Northwest Wood Products Clinic, Spokane, Washington, April 1, 1952 in cooperation with the Inland Empire Section, Forest Products Research Society.

tate the unfastening a cable pulling device has been set up at the mill to slip the cable around the bundle so that the fastener is on top of the bundle.

SOME PROBLEMS

There are many problems which are encountered in the bundling of logs and pulpwood, one of which is the scaling. It is impossible to scale bundles in the water and they must be scaled on the truck. Scaling the uneven length pulpwood also presents quite a problem. Some companies are scaling height and width of load and estimating an average length. Others are attempting to scale the cubic content of each log and applying a solid cubic content per cord.

Another problem is the degree of tightness of the straps on the bundles. Rayonier has found that the straps need not be extremely tight. Apparently much equipment and many straps are damaged and considerable time is lost by trying to tighten straps beyond reasonable tightness. Bundles tend to roll in the storage piles when straps are too tight. When straps are not so tight logs nestle in the storage pile and are more stable. When bundles are dumped in the water the buoyancy of the logs tends to keep the straps tight.

The type of log dump is also important. It should be so constructed that the bundles can be eased into the water with a minimum of strap breakage and in such a manner that the bundle fasteners will remain above the water.

Although there are many problems to solve, the bundling of pulpwood and logs seems to be well worth while in many cases in that it cuts down the number of pieces to be handled and considerably reduces log loss when small logs are put in the water.

Rafting, towing, and storage expenses are also much less in bundled logs. Bundled logs use only about half of the boom sticks and storage space as single log rafts.

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Bundling Sawlogs and Poles[1]

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The practice of bundling logs has increased greatly in the Pacific Northwest since 1945. Probably the major reason for this trend is the expanded utilization of small-sized trees. Economic conditions now make it feasible to harvest the small understory trees that used to be wasted in cutting our old-growth timber and to harvest second-growth timber of small sizes.

This small timber costs more to log than old growth, so loggers have been trying to find ways of reducing the cost of handling them. Packaging small logs looked promising because equipment and methods used for old growth could then also be utilized for handling the bundled logs.

Bundling can be practiced in several parts of the logging operation. So far, though, this method is used mostly in water transportation of logs. There are many reasons for bundling small logs that are to be boomed and towed; the most important advantages are:

1. Practically eliminates loss from sinkers.
2. Reduces towing costs because more logs can be put in a raft.
3. Reduces danger of loss when towing in rough water.
4. Takes less room for storage.
5. Requires fewer chains and boom sticks for the raft.
6. Reduces danger for men working on booms.
7. Lowers insurance rates.

Almost any operator can package his logs. The equipment costs little and the techniques are simple. Several small logs are bound into one unit by encircling them with woven wire rope or steel bands. The number and size of binders per bundle depends on care that it is expected will be exercised in subsequent handling. Generally two bands are used if bundles are lowered into the water and three are needed when they are rolled off the log dump. More and heavier binders will be required on extremely rough handling.

Wire rope binders cost more than steel bands but they can be used many times. Furthermore very good fittings have been developed for wire rope binders, which greatly assist in assembling and b reaking down the bundles.

Steel bands are considered expendable and often are used only once. If the bundles are not stored too long in salt water, however, it is practical to reuse the straps at least once. The most commonly used steel bands are either 1-1/4 inches by .050 inches or 2 inches by .050 inches. Equipment for using these bands consists of a stretcher for tightening the bands, a sealer for crimping a metal seal around the two ends of the band, and a shear for cutting the band. Also, reel stands are often used to hold the banding material. Total cost of this accesory equipment does not exceed $150.

Packaging truck loads of logs before dumping the logs into the water is the simplest method developed to date. Bands are simply placed around the load and tightened by hand. The bands are sealed and cut off and the bundle is ready to be lowered into the water. It has been found that the bundles are stronger if the bands are not too tight; that is why the stretcher is not used for log bundles to be rafted.

Logs are also bundled after they have been dumped into the water. This method is generally used for logs that have not been sorted before dumping. Many techniques for bundling in the water have been developed, but the cost is more than for bundling logs on the trucks.

Bundling logs on trucks takes only a few minutes per load and costs differ little from one operation to the next. Time and methods vary widely in packaging logs in the water and, of course, the costs vary accordingly. One company bundles logs by both methods and has furnished costs.

1. Bundling in water

A "60" gas engine and A-frame are used to bundle logs in water. One man operates the machine and two men sort and band. Twelve thousand logs went into 1,384 bundles, averaging nine logs per bundle. Scaled by Scribner rule this amounted to 6,302,710 feet board measure, or 4,554 board feet per bundle. Cost breakdown was as follows:

[1]Paper presented at the Northwest Wood Products Clinic, Spokane, Washington, in cooperation with the Inland Empire Section, Forest Products Research Society, April 1, 1952.

Cost item	Total cost	Cost per M
Strapping labor	$2,418.00	$0.384
Strapping supplies	1,032.00	.164
Machine fuel, lubrication supplies	397.00	.062
Total bundling cost	$3,847.00	$0.610 per M

2. Bundling on trucks (May 1, 1949 to October 31, 1949)

Logs were banded by two men on trucks just prior to unloading. Total footage bundled was 18,189,000 board feet (Scribner). Cost breakdown was as follows:

Cost item	Total cost	Cost per M
Strapping labor	$3,820.00	$0.210
Strapping supplies	3,311.00	.182
Total bundling cost	$7,131.00	$0.392 per M

Another company recently analyzed the costs and benefits from handling bundled logs. These logs were bundled in the water and steel straps were used as binders. Results of this investigation were as follows:

Costs

Item	Costs per M bd. ft.
1. Bundling labor	$2.00
2. Banding material (including clamps) (6,870 feet of banding material for each 400 M bundle raft at $.022 per lineal foot $163.400 M = $0.38 per M. Using the banding material 1-1/2 times cuts cost to $0.25 per M)	.25
3. Rehandling of used material	.05
4. Depreciation and maintenance of bundling equipment	.15
Total Costs	$2.45

Savings

Item	Savings per M bd. ft.
1. Reduced sinker loss, 4 percent of $40-per-M pulp logs	$1.60
2. Reduced towing cost (Flat raft averaged 185 M; bundled raft, 400 M)	.81
3. Saving in boom sticks (Each bundled raft results in saving the cost of returning 2 sets of boom sticks.)	.20
4. Twenty percent savings on gear.	.27
5. Reduction of raft maintenance (Cost of $0.25 per M on flat rafts to $0.10 per M on bundled rafts.)	.15
6. Reduction of time in handling rafts at mill	.20
Total Savings	$3.23
Less Total Costs	-2.45
Net Savings	$0.78

One disadvantage in handling bundled logs is in scaling. Bundled logs cannot be measured in the water. Therefore, they either have to be measured on the trucks prior to dumping or some other method must be used. It is difficult to measure the large number of logs of varying length on a load. Therefore, some companies have adopted weight as the unit of measure. Each truckload of logs is weighed before dumping. This method of measure is recommended as it is faster, cheaper, and generally just as accurate as scaling. Loggers who sell logs like this method because it gives them an immediate measure of the logs delivered.

Bundling logs to facilitate yarding and loading has been tried but as yet has not been widely adopted. Some operators have placed small logs in a cradle or frame and bound them with steel straps. Loading trucks with bundles is faster than loading individual logs. However, this method has gained little headway. Some companies find it more economical to use preloaders or to employ semitrailers for their small-log operations. Nevertheless, many operators feel that more development work should be given to bundling of logs ahead of loading. Hauling a thousand feet of small logs costs considerably more than for large logs. The difference is due almost entirely to the idle truck time while a load is being secured. Loading packaged logs will speed up production and, therefore, reduce hauling costs.

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Utilization of Western Hardwoods[1]

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I have been asked to talk on the seasoning of California black oak, but I wish to take some liberties with the assignment and discuss the seasoning and utilization of all western hardwoods. After a brief coverage of this larger subject, I shall discuss the important phases of the experimental work recently completed by the California Forest and Range Experiment Station on the seasoning of California black oak.

WESTERN HARDWOODS

There are nine hardwoods in Washington, Oregon, and California that are being utilized, or hold promise of being utilized.

Western hardwoods now being cut include Red alder (Alnus rubra), Oregon ash (Fraxinus oregona), Oregon maple (Acer macrophyllum), Oregon white oak (Quercus garryana), and California laurel (Umbellularia californica).

Western hardwoods not now harvested include Tanoak (Lithocarpus densiflorus), Chinquapin (Castanopsis chrysophylla), Madrone (Arbutus menziesii), and California black oak (Quercus kelloggii).

Hardwoods are being harvested in Oregon and Washington to much greater extent than in California. Red alder and Oregon maple are now moving to furniture manufacturers -- particularly to those in Los Angeles. Oregon ash and Oregon white oak are also cut, but to a lesser extent. These woods find much the same uses, and in addition are used for construction, as door sills, thresholds, interior trim, etc.

As to volume, Oregon is estimated to have 4 billion board feet of hardwoods. For California, estimates vary; there may be 4.0 billion as estimated by the Oregon Forest Products Laboratory. The total for Oregon and California is then approximately 8 billion board feet.

This total volume for the two states compares favorably with stands in some of the eastern states; for example, Wisconsin, with 10 billion board feet and Michigan with 13 billion. These eastern figures include aspen, which has come in on most of the timber lands from which the pine, hemlock, beech, birch, and maple have been removed. Discounting the aspen, the hardwood stands are very similar.

Present utiliation

Why have western hardwoods not been utilized? Chiefly because the manufacture of conifer timber is more attractive financially. Anyone who wants to operate a sawmill has until recently been able to get all the pine, fir, cedar, hemlock, and redwood stumpage or logs he has needed. The cut per day in a conifer mill is greater than in a hardwood mill, and the margin of profit just as high. The conifers have therefore been exploited, and the hardwoods left as submarginal, inferior species.

Then too, the hardwoods are more difficult to season--at least by the standards established in the pine and and fir industries. In fact, some people think seasoning difficulties are the limiting factor in use of our western hardwoods. This belief is only partly true for some of the western hardwoods respond well to seasoning procedures long established and practiced in the hardwood-producing areas east of the Mississippi.

As to ease of seasoning, the nine western hardwoods can be divided into two groups. Those relatively easy to season include: red alder, Oregon ash, California black oak, Oregon white oak, and Oregon maple. Those relatively difficult to season include: chinquapin, California laurel, madrone, and tanoak. Of these difficult-to-season species, tanoak is probably as difficult as any, but even it, with proper treatment, can be dried.

An additional adverse factor is that the hardwoods grow in more scattered stands with lower volumes per acre than the conifers.

Prospects for Utilization

But conditions are changing. Three circumstances in particular are now encouraging the use of western hardwoods. First, there is no longer an unlimited supply of coniferous timber, and many small operators are unable to get the logs they need to maintain production at the high level they consider to be normal. There is little or no competition for the hardwoods, and some small operators have turned to this supply of raw material to keep their

[1]Presented at meeting of Forest Products Research Society, Northern California Section, San Francisco, California, May 9, 1952.

mills operating. Others have started a sawmilling business based on the hardwoods. One operator who came to the annual meeting of Western Dry Kiln Clubs in Redding just last week was Mr. Scotty Edmiston of the Oregon Alder and Maple Company, of Willamina, Oregon. I think it likely that more mills will begin to cut hardwoods for part of a shift or for a day each week as the harvesting of our western hardwoods becomes more attractive.

Second, the western hardwoods are becoming established on the lumber market. Oregon maple, Oregon ash, and red alder now are well established; Oregon white oak and California laurel are established on a smaller scale. California black oak is not yet established, but the indications point to early acceptance in the lumber trade. The other three species, tanoak, madrone, and chinquapin, will come into their own as the pressure for closer utilization develops.

Third, the West is still in the era of harvesting virgin forests. We are only beginning to harvest second-growth timber. As time goes on, the average size of the trees cut will become smaller. Then the size and volume per acre of hardwoods will appear relatively good. A look at the lumber industry elsewhere will substantiate this. The Tennessee Valley Authority recently published a report on logging and milling costs called "Effect of Log Size and Grade on Production Rate and Lumber Grade in Shortleaf Pine." I quote "...During the first eight-hour day 535 logs having an average diameter of 6.4 inches were sawed into 8,509 board feet of lumber. In 11 hours of the second and third days 288 logs with an average diameter of 10.9 inches were sawed into 19,633 board feet of lumber". Their small logs averaged 6.4 inches in diameter inside the bark and sawed out less than 16 board feet per log. Their large logs averaged 10.9 inches in diameter inside the bark and sawed out less than 70 board feet per log.

At a recent meeting in Madison, Wisconsin, I heard reports from the South and Southeast of sawmills competing with pulp mills for raw material, and sawmills cutting 2 by 3-inch dimension; one piece per log. The logs were too small to saw out the conventional 2 by 4-inch dimension. One mill was laminating 1 by 4-inch to make 2 by 4-inch dimension for construction.

In the Northeast the grading rules provide for five classes of logs: veneer logs -- 2 grades; factory logs -- 3 grades; tie and timber (structural) -- 2 grades; local use; and bolts -- 3 grades. Yet there exists a need for an even lower grade of log that is now sawed at small mills.

Western hardwood logs would look mighty good in such a market. In one California black oak seasoning experiment, seven trees were cut. These trees were bucked into 13 logs, which sawed out 4,200 board feet of 4/4 lumber, an average of 600 board feet per tree or 323 board feet per log. We can expect timber of this size to reach the lumber market as conditions become right.

SEASONING CALIFORNIA BLACK OAK

Now, let's look at the experiments conducted by the California Forest and Range Experiment Station to develop a drying procedure for California black oak.

A full description of the test material, test procedure, and results are contained in two reports, "Seasoning of California Black Oak", Research Note No. 62, and "Further Experiments in Seasoning California Black Oak", Research Note No. 75, copies of which are available on request from the California Forest Experiment Station at Berkeley.

First Experiment

In the first of these two experiments, 18,000 board feet of 3/4-inch lumber was sawed into 3-inch and 6-inch strips at the Diamond Match Company Mill, Stirling City, California. In this first test these relatively thin, narrow strips were used because, other things being equal, such boards are dried more easily than thick, wide boards.

The lumber was piled in 4 by 4 by 16-foot packages or units, using 1 by 2-inch stickers spaced 2 feet apart, and placed on the yard for air drying. A demountable dry kiln from the Forest Products Laboratory, Madison, Wisconsin, was set up at Stirling City, and both green lumber and air-dried lumber were kiln dried. Four experimental runs were made in the small kiln and one in a large commercial kiln located at the Diamond Match Company plant at Chico.

This thin lumber air dried to an average moisture content of less than 30 percent in only 25 days of good drying weather during June and July. The oak at a moisture content of 20 to 30 percent could then be kiln-dried to a final moisture content of 10 percent or less in 30 to 50 hours, depending upon the severity of the drying conditions. No serious drying defects developed during air-drying or kiln drying. These results showed that California black oak can be dried as readily as eastern red oak. In fact, we lost no stock due to drying defects except in a kiln charge dried green from the saw. California black oak is similar to the

eastern red oak in this respect also. It is difficult to kiln dry from the green condition without surface checks and honeycomb. These 3/4-inch strips were manufactured into standard 1/2-inch T&G flooring and sold through one of the Diamond Match Company's retail lumber yards.

Second Experiment

A second series of experimental kiln runs were made at the High Sierra Pine Company in Oroville, using full-inch-thick, wide-width lumber. The 4/4 random width oak lumber was again piled in 4 by 4-foot units, using 1 by 2-inch stickers, 2 feet on centers. The lumber lost about 80 percent moisture content in 60 days on the yard, during September and October. Again there was no appreciable drying degrade during yard drying, and the air-dried stock was kiln dried to a final moisture content of 8 percent in 8 days in the experimental dry kiln and to a final moisture content of only 6 percent in 7 days in a commercial kiln using somewhat more severe drying conditions. There were no drying defects during kiln drying. The slight end-checking that developed during air drying was considerably less than developed in ponderosa and sugar pine in adjacent piles. This lumber was remanufactured into interior paneling and used in a fine home built in Oroville.

These experiments in air drying and kiln drying California black oak, viewed against my previous experience in experimental and commercial drying of hardwoods, lead me to believe the local black oak can be dried successfully on a commercial scale. Seasoning need not be a limiting factor in the full utilization of this species.

Current Seasoning Work

Two other experiments are now in progress. The Union Lumber Company, Fort Bragg, has on the drying yard unit packages of tanoak, madrone, laurel, and chinquapin approximately 1-1/2 inches thick, These hardwoods have dried to a moisture content ranging from 31 percent for the laurel to 64 percent for the chinquapin after one year on the yard (April 19, 1951 to April 3, 1952). This lumber is now sufficiently dry to be finished off in the dry kiln rapidly and with little danger of drying defects. We believe it may be dried below 30 percent by late summer or fall when we plan to complete the experiment.

The Pacific Lumber Company, Scotia, has on the drying yard unit packages of madrone and tanoak, 3/4 inch and 1-1/4 inch thick. After a full year on the yard the thinner stock had dried to a moisture content of less than 20 percent and the thicker stock to a moisture content of 30 to 35 percent. One unit of the thin stock was kiln dried to a final moisture content of 4 percent in 7 days. There was no degrade during kiln drying, though many boards showed cup and twist during air drying.

This experimental material is all ready for final kiln drying now and we plan to complete the last phase of the study this spring.

Results to date indicate these species (tanoak, madrone, chinquapin, and laurel) will always be difficult to dry without checking and warping. This does not preclude their full utilization, however. Other hardwoods that are equally difficult to season are now utilized. Beech is prone to check; sweetgum dries slowly with persistent water pockets; tupelo gum warps and twists badly during drying. These are only a few of the species that operators in other areas are now using despite inherent objectionable drying characteristics. It seems clear that Western operators will learn to use Western hardwoods.

Utilization of Bark[1]

WILLIAM G. VAN BECKUM, Weyerhaeuser Timber Company, Longview, Washington [2]

INTRODUCTION

Bark is Nature's protective clothing for the millions of trees that grow in the forest and on the landscape of the world. A cloak of relatively thin bark is sufficient to insulate and to guard such trees as beech and birch from the attack of insects and decay whereas thick, rugged bark in multiple layers protects such giants of the forest as the Douglas-firs of the Pacific Northwest and the California redwoods.

Although essential to the health and growth of the living tree, bark once removed from the tree, for centuries, has been of only limited value to man. The early American Indians fabricated canoes from the bark of the birch tree; certain medicinal values have long been recognized in the bark of the cascara tree; in a more modern vein, bark has found limited industrial application as a domestic source of tannin and in the manufacture of certain chemicals such as basic lead carbonate for the paint industry.

Bark utilization such as this was in pace with the world's industrial development of an earlier day. Today, however, the picture is changing rapidly. Confining our thinking solely to America, a multitude of saw mills, gigantic pulp mills, and plywood mills, together with a variety of other forest products industries scattered throughout the forested regions of the nation all combine to consume an enormous tonnage of wood each year.

In almost every instance, bark must be removed from the log before it becomes a suitable raw material for processing in the forest products industries. In its natural form as removed from the log, bark is of little value to these industries except as fuel, and in most areas there is an overabundance of bark for fuel purposes. Thousands of tons of bark find their way to the waste burner every day. High logging costs, high costs of transportation, high costs of manufacturing have all gone into the tonnage of bark that accumulates at the mill site and, unless it is to be burned as fuel or waste, high costs of disposal will be added before these tons of bark are suitably removed from the site of manufacturing operations. All these factors and more point to the justification and the need for further developing the industrial utilization of bark.

The forest products industries today are taking a definite progressive attitude toward greater bark utilization. Our own organization is concentrating attention particularly on Douglas-fir bark in view of the substantial tonnage of this species available at our various manufacturing operations. For example, over a million board feet of logs, still wrapped with bark that for so many years gave protection from insects and injury in the forest, arrive each day at our Longview operations alone. Of this amount, some 800,000 board feet are Douglas-fir. With bark accounting for approximately 12 percent of the weight of these logs, the tonnage of bark arriving at our Longview operations is in the neighborhood of 200 tons each day. Multiply that figure by the number of other mills processing Douglas-fir and you have an enormous tonnage of bark demanding proper utilization.

DEVELOPMENT OF DOUGLAS-FIR BARK HERE

Intensive development work on the utilization of Douglas-fir bark began about 1940, progressing through various laboratory and pilot plant stages to the point where a production plant for the manufacture of bark products was constructed and began operation in 1947. Since then, five principal and several secondary bark products have been steadily moving out of this plant in carload quantities to a variety of industrial markets throughout the United States.

Bark raw material for operation of the plant comes primarily from the adjoining plywood plant. Here a specially designed compression barker strips bark from peeler logs, and the bark moves by conveyor to the bark products plant for further processing. Another large, barely tapped source of bark is available in our sawmills where sawlog barking has been practiced for several years, one hydraulic barker having operated during that time with a second hydraulic barker scheduled to go into operation within the next month.

The manufacture from Douglas-fir bark of a group of products of widely different physical and chemical characteristics is possible because of the different constituents that make up

[1] Paper presented at Northwest Wood Products Clinic, Spokane, Washington, in cooperation with the Inland Empire Section, Forest Products Research Society, April 1, 1952.

[2] Now with Pacific Lumber Co., San Francisco

the bark. There are three major components of fir bark -- layers of cork, short spindle shaped fibers and a fine amorphous powder. Differences in physical properties of these major components allow their separation by mechanical methods into pure cork, pure fiber, and powder, or into blends of these ingredients. The products thus manufactured are known commercially as Silvacon.

DIVERSIFIED USES

Industrial utilization of the Silvacon products is quite diversified. One large market here in the Pacific Northwest is as an extender for adhesives used in the Douglas-fir plywood industry. The demand for Silvacon 472 in this industry is increasing steadily, as a result of the high quality, low-cost adhesives that are possible through use of this product. An additional attractive feature that Silvacon 472 offers to the plywood industry is that it can be used in both exterior and interior grade adhesives.

The plastic molding compound industry is another well established market, with substantial tonnages of Silvacon being shipped regularly across the continent to the Eastern Seaboard. Large, nationally known molding compound manufacturers utilize the natural plastic characteristics that Silvacon possesses to advantage in the compounding of various phenolic plastic molding compounds. These plastic or flow properties of Silvacon enable the manufacturer to conserve on resin usages in a number of different formulations without sacrifice of quality. Another attractive property of Silvacon in molding compounds is its ability to increase impact strength. This characteristic is displayed chiefly by the more fibrous Silvacon products.

Silvacon 412 finds a rather unique outlet in oxychloride or magnesite cements. In addition to finding application in industrial and office building flooring, Silvacon-filled oxychloride cement is also being used as a flooring in renovating boxcars. A specially developed formulation for this use is known commercially as Plastinail flooring, a name derived from the fact that the plastic cement flooring is nailable. Blocking or crate-fixing nails can be applied in any location in the car, and when the car arrives at its destination these nails can be readily withdrawn with little or no chipping of the flooring. Other features of Plastinail include flexibility, high strength, smoothness, and ability to prevent leakage of bulk materials. Plastinail is easily applied. It responds readily to troweling which allows rapid application and, because of rapid cure, a minimum of in and out time is required for renovating a car in the railroad shops. Hundreds of test cars are rolling over the nation's rail lines today as the railroads closely observe their performance to determine the long range possibilities of Plastinail, not only in boxcar flooring, but as a car siding material as well.

Quite apart from its use in oxychloride cements is the use of Silvacon as a conditioner for fertilizers and insecticides. Fertilizers that tend to cake during storage can be maintained in pourable condition through the incorporation of small quantities of Silvacon 412. Equally small amounts of Silvacon 490 assist in the manufacture of DDT formulations, keep these in fine powdered condition in the final stages of spray drying. Though the quantity of Silvacon used in these applications generally amounts to 2 percent or less of the total fertilizer or insecticide by weight, Silvacon is regularly shipped to these industries in carload quantities.

The rubber industry uses Silvacon to increase flex life in certain rubber sole formulations and to increase air entrainment and to reinforce special types of sponge rubber. A more novel use being developed for Silvacon 490 in the rubber industry is as a dispersing agent for carbon black in connection with master batching the latter with rubber latex. Silvacon 490 is also being evaluated as a dispersing agent for use in other industries such as the manufacture of ceramics.

Asphalt roof coatings contain Silvacon 412 as a filler and stabilizing agent, the latter property of Silvacon being due in part to certain antioxidant characteristics that it possesses. Silvacon is used in foundry sands where it improves sand flowability and contributes to the elimination of spalling, veining and other casting defects.

Diversified utility for several of the Silvacon products has been established in the oil well drilling industry in connection with that industry's use of drilling fluid, or mud, as it is commonly called. Drilling mud is a very important tool to the oil well driller. First of all it serves as a lubricant for the bit as it bites into the sand, gravel and rock formations of the earth. Then as the mud circulates down the drill pipe, out at the bit and back to the earth's surface it carries the great assortment of cuttings gouged out by the bit as the latter digs deeper into the formation. Another function of drilling mud is to prevent the collapse of earth formations into the well and also to prevent the seepage of gas pockets into the hole, thus practically eliminating the danger of blowouts and the old-time gushers.

As the drilling mud circulates and carries out its functions in the well, it becomes thick and heavy due to chemical action of various salts and minerals of the earth that come in contact with it. In order to return the mud to a more fluid condition so as to keep it pumpable and generally more useful, certain chemical dispersing agents are added at this point. Silvatan is a product that we have developed for this purpose. Relatively small quantities of Silvatan will readily restore a thick, highly viscous mud to a water thin fluid.

Silvacon 100 is another product developed for oil well drilling particularly for so-called "completion" fluids, the type of drilling mud frequently used as the bit encounters oil bearing formations. Great care must be taken to prevent drilling mud from entering oil bearing strata for if this occurs, mud often seals off the small capillaries in such formations and retards or prevents the flow of oil into the hole. Silvacon 100 effectively seals these oil bearing sands at the well wall thereby reducing mud penetration and permitting a better flow of oil into the well.

Frequently, as drilling progresses in a given well, the bit encounters porous, gravelly and fractured formations and, in some instances even cavernous areas are met. Drilling mud seeps away into these faults at a rate dependent upon their size and when the loss of mud becomes substantial, drilling must cease because mud is no longer present to carry on its important functions mentioned above. This loss of mud is termed loss of circulation and one of the effective methods of restoring mud circulation is to seal or plug the faulty formations.

One of the flake-like, cork products from Douglas-fir bark, known to the drilling industry as Silvaflake, is an effective agent for restoring loss of circulation. Carloads of this product are moving into all the major oil well drilling areas of the country. Another product, Superbridge, made from the fibers of Douglas-fir bark, serves much the same purpose in drilling muds. Both Silvaflake and Superbridge are tailor-made products to do specific jobs in combatting lost circulation. A third lost circulation product that we manufacture is known as Silvacel. This is a carefully blended mixture of a bark product similar to Silvaflake together with wood fibers from sound Douglas-fir wood. As an indication of the importance of products of this type to the drilling industry as much as a full carload or more of lost circulation material is occasionally pumped into a single well.

The uses described above illustrate the more important markets that have been developed for Douglas-fir bark to date. In addition to these there are, of course, numerous other possible applications under constant investigation. Existing products continue to find expanded markets, and as special problems arise in varous industrial fields, efforts are directed toward producing tailor-made bark products better suited to the specific requirements of these industries.

Needless to say, there are numerous obstacles to be overcome in introducing and expanding the uses for new products of this type on a national scale. Not the least of these hurdles is the high cost of transportation to the large eastern industrial markets. Then there is the matter of competition from other materials. Some of the uses that have been developed for Silvacon show the product to be outstanding. In other uses, competition from materials that have been in use for many years is keen. These, and many other problems of manufacture and marketing are regularly met and they must be successfully overcome.

These difficulties notwithstanding, Douglas-fir bark products by their unique characteristics have already adequately demonstrated their value to the nation's industrial picture. This, together with the justificatons that exist in the forest products industries for developing greater bark utilization, is a combination that spells real encouragement for the future to ourselves as suppliers of bark products, and to a broad cross section of the nation's industries as consumers of these same materials.

JOURNAL of the FOREST PRODUCTS RESEARCH SOCIETY

The Wet Batch Process of Hardboard Manufacture[1]

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The wet batch process for the production of hardboards discussed here was developed by Ralph Chapman of Corvallis, Oregon. It differs from the conventional wet batch process only in the method of forming the wet lap or mat before pressing. There are three commercial plants using the Chapman process in the United States and Canada at the present time. A plant using this process is now being built in Italy.

TYPE OF RAW MATERIAL

The type of raw material used in the process differs in no way from that used in other wet processes. Either softwoods or hardwoods may be used. Waste from veneer plants and sawmills can be used as can also slabs and edgings, with or without bark, and mill trims.

The plant in Corvallis is at the present time using only Douglas-fir slabs as raw material.

DEFIBRATING

In order to produce a suitable fiber for this process, the chips after being screened, are passed through an Asplund defibrator and then refined in a Bauer refiner. Other defiberizing machines, however, might be found just as suitable for the defibrating. The types of grinding plates also will vary, the choice depending upon the raw materials and the desired type of finished product.

When an Asplund defibrator and a Bauer refiner are used in series, the chips are fed first into the preheater of the Asplund and are steamed under 100 to 160 lbs. steam pressure for from 45 to 60 seconds. The heating of the ligno-cellulosic material softens the middle lamella, facilitating the defibration of the chips. The chips then pass from the center of the Asplund defibrator outward between two grinding plates, one stationary and one rotating. The fibers are discharged through a blow valve and piped into a Bauer refiner where they are further refined. Plate settings in the Bauer depend upon the desired size of fibers and the species of wood used. The pulp then passes into the stock chest over a consistency regulator which maintains the consistency of the defiberized material usually between 2 and 3 percent, based on oven dry weight of the fibers.

[1]Paper presented at Northwest Wood Products Clinic, Spokane, Washington, in cooperation with Inland Empire Section, Forest Products Research Society, April 2, 1952.

ADDITIVES

Additives, such as binder, size, wax, etc. are added to the pulp in the stock chest. The pH necessary to precipitate the material on the fibers is controlled by the addition of alum or sulphuric acid. Normally from 1 to 3 percent, on a solids basis, of water-soluble, thermosetting phenolic resin is used and from 1 to 3 percent of wax. After agitation to obtain a complete distribution of additives, the stock is conveyed by pumping to another chest under the forming machinery.

MAT FORMING OR FELTING

The forming equipment consists of a 4 by 8 foot deckle box. The upper part is lowered or raised by air cylinders. The upper part is forced down pneumatically on an endless screen which also passes between the platens of the cold press. In the lower part of the box, vacuum is applied to suck the water out of the stock, forming a thick mat.

To form a mat, the box is lowered onto the screen and stock from the chest is pumped at a continuous rate of flow through four "swing spouts", into the forming box. The spouts pass over the box at a predetermined speed, depending upon the desired thickness of the finished board, and then return to the discharge side. The spouts when not over the deckle box, discharge back into the chest, keeping the stock constantly agitated. When the spouts return to the discharge side they activate a switch, which in turn activates valves and vacuum is pulled on the mat from underneath the screen. On a predetermined time cycle, depending upon the thickness of the board the air-cylinders on the forming box are activated, the top section of the forming box raises, a chain drive carries the screen and the formed mat into the cold press or prepress. Another cycle is now ready to begin. The closing of the prepress and the lowering of the forming box are simultaneous.

Excess water is removed in the prepress. On leaving the prepress, the mat has a moisture content of approximately 170 to 200 percent. From here, the mat is carried by belts on a tipple into loading racks where the mat is supported on rollers alone.

When the loading rack is full, the forming operation is stopped; the mats are then carried onto screens which are fixed to the lower platen of the press and the pressing cycle beings.

PRESSING

In this method of manufacturing hardboard, the pressure used varies from 250 to 500 psi. depending upon the wood used and type of board desired. It is customary to use a higher pressure during the first part of the pressing cycle than during the latter part. The temperature of the platens is approximately 300 to 400 degrees F. and time of the cycle from 6 to 15 minutes, depending upon thickness and type of board made.

When the pressing cycle is completed, the board is discharged into a rack and the rack goes through a humidifier where the board is brought up to a moisture content of 5 to 10 percent. The boards are then trimmed to size and wrapped for shipping.

Any tempering, or other treatment of the board, is done before humidification.

One noteworthy part of this process is, that the complete felting and loading operation can be stopped and started by one button on the press control panel without affecting the operations before or after the forming section.

ADVANTAGES OF THE CHAPMAN BATCH PROCESS

1. Low capital investment.
2. Ease of control of the forming section.
3. No cutting of the wet lap is necessary, inasmuch as the individual mats are formed in the forming box and the forming wire is stationary during this cycle. This method eliminates directional orientation of the individual fibers which is found in the continuous wet process.
4. A simple and inexpensive type cold press is possible, as compared to the pony presses and suction couch roll sections of the continuous wet process.
5. It eliminates the speed changer or accelerated roll section which is necessary to gain space between the mats of the continuous process.
6. The length of the forming line is shortened which allows lower building cost and consumes less man-hours for control.
7. Auxilary equipment is less complex and, therefore, power requirements are lower.

JOURNAL of the FOREST PRODUCTS RESEARCH SOCIETY

The Wet Continuous Process of Hardboard Manufacture[1]

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INTRODUCTION

The wet batch process of hardboard forming described differs basically from the wet continuous felting in that formation of the fiber mat prior to pressing is accomplished by a batch operation. The process to be described here is continuous formation. This may be accomplished by means of the fourdrinier former or the suction cylinder as compared to batch forming in large sheet molds. In both processes, water is first removed by gravity and then by suction. This is followed by subsequent pressing to further remove water. Pressing of the wet lap in the continuous system is accomplished by means of a series of roll presses, some of which may be suction rolls. In the batch method, this water removal is carried out by pressing cold with a platen press.

The fourdrinier type of forming will be described here.

ESSENTIALS OF THE PROCESS

Fiber, suspended in water of a controlled freeness and consistency, is either fed by gravity or pumped into a head box prior to entry onto the moving wire. The purpose of the head box is to regulate the flow of stock onto the wire to attain a mat of uniform thickness and density. Free water is drained by gravity from the mat as the wire travels on the forming table. As the wet mat travels along, it is carried over suction boxes which remove additional water. The wet lap then enters a press roll section. A top wire felt is used in this section which helps to retain the mat while it is under pressure. The press section for continuous forming machines will vary considerably depending on the drainage characteristics of the sheet and speed desired. These presses may be either plain or with suction on top or bottom or both.

Suction slices may be placed back of the presses to remove the pond of water accumulated there. The fiber leaves the press section at 50 to 60 percent water, is edge trimmed and cut to size for entry into the loading rack prior to pressing.

[1] Paper presented at the Northwest Wood Products Clinic, Spokane, Washington, in cooperation with the Inland Empire Section, Forest Products Research Society, April 1, 1952.

ADVANTAGES

There are two prime advantages apparent in the continuous wet system, -- namely, volume production and uniformity of sheet formation.

The batch process has confined itself to a maximum sheet length of 8 feet whereas all of the larger producers of hardboard utilize 12, 16, and 18 foot presses. Masonite feeds several presses with one machine. Some of the newer mills with one press may find it advisable to augment that one press, for American industry while often starting in a small way, gets growing pains and expands. The continuous process is readily adapted to this situation.

The disposition of fiber continuously on the moving screen gives a sheet of more even caliper and surface quality than the batch type formation. These factors lend themselves more readily to uniformity and control.

OVER-ALL PLANT OPERATION

The Oregon Lumber Company is using the wet continuous process at Dee, Oregon. The operation was designed with production in mind and is so arranged that the production can be doubled with minor alterations.

As the waste wood leaves the present saw mill, it travels on a conveyor over a grated hog where material unsuited for chipping is removed reduced to hog fuel and returned to the boiler plant.

Slabs and edgings that pass through are spray-washed to remove sawdust or dirt before entering the chipping plant. Here, the material is reduced to chips and conveyed to a screen for removal of oversized chips which are shaken down into a rechipper and recirculated over the screen.

The chips are then conveyed to a storage silo. They are fed from the silo by means of a continuous rotating feed onto a driven rubber belt. The belt feeds the chips to bucket elevators which in turn transfer them to a conveyer. This conveyor constantly supplies the hoppers to the Asplund screw feed, sending any surplus back to the storage bin.

The chips are then fed into the Asplund preheater. Here, a plug of chips is formed and chips are continuously fed and reduced to fiber under pressure. The defiberized chips are collected in a cyclone, diluted with water to 6 percent consistency and fed to refiners where the fiber bundles are further refined.

This refined fiber is further diluted with water and collected in stock chests. The fiber slurry is pumped from the stock chest to a consistency regulator which regulates the ratio of water to fiber. The mat is then continuously formed and cut to size as previously described. The wet mat leaves the forming machine and is carried by speed-up rolls under a vacuum transfer. Here the sheet is picked up. Carrier plates having a screen on the surface enter and the mat is placed on the plates and transferred to a press loading rack. Here, twenty 4 by 16-foot sheets are accumulated and charged into the hot press where they are consolidated into hardboard.

After the boards are pressed, the plates are pulled from the press into an unloading rack. Formation of the sheet is synchronized so as the press load is discharged, another load enters. The sheets are then unloaded onto a conveyor table where the hardboard is automatically stripped from the plate. The plate is transferred back to pick up another sheet and the stripped hardboard enters a tilt table which moves it into a continuous humidifier. The humidifier is so constructed that the hardboard is fed on edge by the tilt table through a slot into supporting grooves. As one enters, one is ejected into another tilt table so, at maximum production, a two-hour humidification is possible. The humidifier is of circular design to get the greatest utilization of floor space. On leaving the humidifier, the material is graded, sawed, and wrapped preparatory to shipping.

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Features of the Hardboard Industry in Scandinavia and Their Application to United States Developments[1]

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INTRODUCTION

We all know that ways of life are greatly different in foreign countries than in the United States, and many of us have glimpsed this first-hand. My own experience was in the form of an unofficial technical-assistance program to a newly built, 30-ton-per-day softboard mill located in southern Norway. During the course of a year's stay, I became acquainted with some of the economic and natural-resource limitations with which the Scandinavian people must deal. These limitations on over-all technological development, even in a comparatively advanced nation such as Norway, tend to retard the rate of industrial growth.

It is the purpose of this paper to describe some of the differences in economic and technological conditions between Scandinavia and the United States, particularly as they relate to the production of hardboard.

SCANDINAVIAN FOREST PRODUCTS UTILIZATION AND THAT OF U. S. COMPARED

There are some basic data regarding the Scandinavian structural fiberboard and timber industries that one should grasp as essential background information. Figures 1, 2, and 3 indicate some significant comparisons of our nation's wood utilization with that of the world, and of the Scandinavian area in particular. Figure 1[3] compares the pattern of timber end-use of the world with that of the United States. The United States, with about 7 percent of the world's people, cuts 20 percent of the world's timber. Although the large amounts of wood waste in the United States constitute a continual problem, we are not cutting so high a percentage for fuel as the rest of the world.

Proceeding from the timber industry as a whole to the one of specific interest, the field of sheet-wood material, Figure 2[4] compares plywood-production data. The overwhelming dominance of the United States in total production is apparent. On a per capita basis, however, Finland outranks the United States nearly threefold. Nevertheless, because plywood is a major export item in Finland, actual domestic consumption is less in that country than in America.

Comparisons of fiberboard production Figure 3[5] again illustrate the over-all dominance of the United States in the world scene. Sweden's output per person, however, is much more than per capita production in the United States, and its domestic per capita consumption is about ten times that for the United States. In the lower section of the chart, the usage per person of plywood and hardboard is combined, and the compensating effect of the high plywood production of the United States becomes apparent.

These comparisons illustrate, to a limited extent, how a nation's economy responds to its needs in developing the available resources.

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[1] Presented at Northwest Wood Products Clinic, Spokane, Washington, in cooperation with the Forest Products Research Society, April 1, 1952.

[2] Maintained at Madison, Wisconsin, in cooperation with the University of Wisconsin.

[3] Source: Yearbook of Forest Products Statistics, Food and Agriculture Organization of the United Nations, 1950.

[4] Sources: Timberman, Vol. III, No. 3, 1952, for United States plywood (softwood only) production and home consumption; Yearbook of Forest Products Statistics, Food and Agriculture Organization of the United Nations 1950, for production and home consumption of other countries; United States per capita consumption includes hardwood-plywood production estimated as 20 percent of softwood-plywood production.

[5] Sources: Yearbook of Forest Products Statistics, Food and Agriculture Organization of the United Nations, 1950, for production; Timber Statistics, Vol. II, No. 4, Food and Agriculture Organization of the United Nations, for Swedish consumption; United States consumption based on estimated daily capacity of four hardboard plants in 1949 and hardwood-plywood production estimated as 20 percent of softwood-plywood production.

HARDBOARD INDUSTRY IN SCANDINAVIA

SCANDINAVIAN FOREST CONDITIONS

The huge trees that are a basic element in the United States softwood plywood industry simply do not exist in the Scandinavian region. The annual forest growth per person in Sweden however, is about 3 times that in the United States, and in Finland it is at least 10 times as much.

Perhaps the most straightforward way of discussing the Scandinavian fiberboard industry is to take up a stepwise approach paralleling the manufacture of the product, which is mostly hardboard.

Scandinavian forests are characterized by slow-growth, small trees and are generally well managed. The predominant growth is in spruce and pine, but a significant amount of birch, largely unused at present, is also available. The major timber stand is about 1,000 miles north of our Pacific Northwest forests. There is virtually no fire hazard to contend with, and in most of Sweden and Finland logging conditions are favorable. Many plants get their logs by river and are located at tidewater; for them, pollution and transport to world markets present no serious problems.

Logs are usually stripped of bark in the woods, so that bark disposal or use in the product is of little importance.

INDUSTRY CHARACTERISTICS

A strong trend toward integrated utilization is encouraged by close governmental control of timber drain. The raw material for fiberboard mills is primarily slabs and edgings. Compared to United States concepts, these integrated installations are relatively small. The plant in Norway where the author was employed is an example; it consists of a sawmill, a mechanical pulp mill, a dry kiln, a planing mill, a hardwood flooring mill, a steam plant, a hydroelectric power station, and the softboard mill. This operation consumes about 200,000 board feet a day. The board plant utilizes sawmill waste and pulp screenings from the groundwood mill.

The Scandinavian fiberboard-production process is virtually standardized. In contrast, the United States fiberboard industry is notable for its diversity in both raw materials and processing methods. The process uniformity in Scandinavia is traceable mainly to the leadership of a Swedish firm that supplies not only fiberizing machinery, but also comprehensive plant-engineering service. The hardboard made by this firm's process dominates Scandinavian output.

The usual Scandinavian plant design is based upon the wet-pulping process, and capacity is predicated on a single multiple-opening press, generally of 35- to 80-ton daily capacity. The primary pulping is done with a disc-type fiberizing machine, and that portion of the stock needing additional refining is processed in continuous beaters or disc refiners. The wet pulp mat is continuously formed on a Fourdrinier-type machine. The plants are of good design and permanent construction and are thoroughly mechanized.

Hardboard and softboard mills are often combined to achieve economies in construction, maintenance, and operation. About three times as much hardboard as softboard is produced in Scandinavia. In comparison, the United States makes about 2 tons of softboard for every ton of hardboard.

Equipment

The international character of equipment in foreign plants causes involved procurement and maintenance difficulties. There frequently will be processing machines from Sweden, motors from England, and control equipment from the United States and Germany. Bearing sizes are usually in metric units, but not always. Nuts and bolts are usually in English sizes, but not always. Structural steel will show a similar birthmark effect.

The heavy machinery is generally of good design and sturdy construction, but the lack of standardization is a continual problem. Strangely enough, the advantages of standardization are not appreciated by many engineers and industrial managers. For example on successive purchases of electrically powered fork-lift trucks by one company, two different makes were bought. One model used lead batteries; the other had an alkaline type. Different rectification units were necessary. These fork-lift trucks were used in adjacent warehouses, and their charging stations were less than 150 yards apart.

Cost Factors

The distribution of operating costs is not the same in these countries as in the United States. Electric power from hydro sources or generated with waste wood as a fuel is cheap. Steam from imported fuel oil and coal is expensive. Labor costs are substantially lower than in the United States. The comparative economics of a resin-based type of board and the conventional fiberboard distinctly favor the wet process in Scandinavia. Phenolic resins

are imported and are not available in large tonnages, while power, water, and a highly developed technology are readily available for the wet process. The high cost of imported fuel may tend to encourage dry forming, but it appears doubtful that a resin-bonded board will be of competitive significance for some time in these countries.

Marketing And Use

Structural fiberboards are marketed via a distribution pattern that is decidedly different from United States practice. The United States manufactures for the home market, while the Scandinavian fiberboard industry depends for its existence largely on export markets. The maze of regulations and agents required inevitably increases distribution cost compared with those within a single nation.

The major use of hardboard is in construction, and it is only beginning to be used for manufactured products or expendable items. The close governmental control of new investment and foreign trade simply does not allow the freedom for trial and error in new enterprise that is an integral part of our economy.

This has been only a brief statement of the contrast of the hardboard industry in Scandinavia with that in the United States. I believe, however, that it illustrates that, although we can partially transfer a technology from one country to another, the ultimate practical solution must be adapted to the particular circumstances of each region. This is not easily nor quickly done. It is a stepwise, tedious, and at times an expensive procedure.

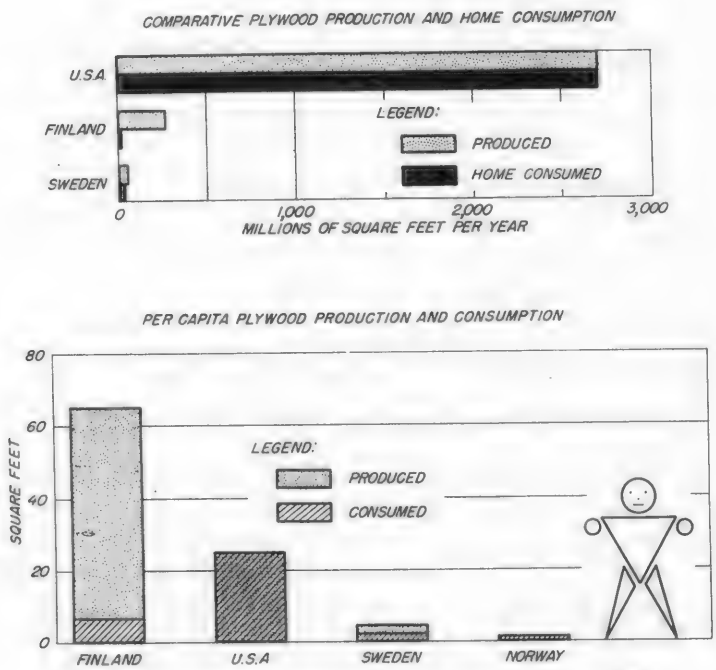

Figure 2.--Comparative plywood production and home consumption.

Hardboard Properties as Affected by Volatile Content of Resin Treated Fiber[1]

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This paper is intended to present and discuss some basic factors influencing the properties of hardboard, with considerable emphasis placed on fiber volatile content. The moisture content is considered in this paper to be moisture present in the fiber prior to treatment with the resin. The volatile content is considered to be the moisture content of the fiber plus the resin volatiles, including water from the resin solution, contained in the fiber after being treated with the resin.

Monsanto presented a paper in the East in 1949 on work covering wood waste of the granular type when used with a powdered phenolic resin. This paper will cover work on a smooth two-side 1/4-inch board with a fiber type of waste and a 43 percent resin-solids, liquid, phenolic resin, Lab. No. 2469.

Ordinarily, a paper of this type would discuss experimental procedure, testing methods, results and conclusions, in that order. We will reverse this method and start with conclusions immediately. We will attempt to show that within the limits of this study, using dry ground Douglas-fir fiber produced by an Allis Chalmers inter-plane grinder and treated with 43 percent resin-solids, liquid, phenolic resin that:

(1) The density of wood waste boards increases with increase in liquid resin content of the treated fiber and very markedly with increase in pressure.

(2) An increase in liquid resin content of fiber used for panel production increases its flexural strength, and pressure increases flexural strength.

(3) An increase in liquid resin content reduces water uptake and swelling of wood waste boards.

(4) Longer pressing times are required as the volatile content is increased.

(5) The pressing time at which flexural strengths of the panel remain constant may be considered the minimum pressing time necessary for the conditions used, and additional pressing time after this level has been reached contributes little to flexural strength.

(6) Increased temperature reduces pressing time and increase in temperature has no appreciable effect on ultimate strength.

(7) The volatile content of the resin treated fiber at the time it is pressed has a very marked effect on density, flexural strength, tensile strength, water uptake and swelling; and the optimum values for each of these properties with this fiber and this resin were obtained at a volatile content of approximately 35 percent, which is very near the normal fiber saturation point.

Figure 1 shows the increase in volatile content of treated fiber obtained when percentage of liquid resin is increased. Remember that a 43 percent resin-solids, liquid, phenolic resin was used in this study.

RESULTS

Effect of resin content and pressure on density of wood waste boards

The effect of resin content on the density of wood waste boards produced from Douglas-fir fiber at a moisture content of 12.5 percent based on the weight when oven dry (bone dry basis or BDB), is shown in Figure 2 inwhich density is plotted against the percent resin solids based on weight of bone dry fiber when pressed at either 200 or 400 psi. without prior drying or other alteration of the volatile content resulting from the resin application.

Figure 2 shows that density of boards increases with increase in resin solids when added in the form of a liquid resin and very markedly with increase in pressure. The ratio of density increase to increase in resin content is greatest at the lower resin contents.

It is also apparent that the pressure used in panel forming is one of the major factors affecting density. Pressure increase from 200

[1]Presented at meeting of Forest Products Research Society, Northern California Section, San Francisco, California, May 9, 1952.

psi. to 400 psi. gave a density increase of 0.18, which was almost the same for all resin contents used in the series.

Effect of resin content and pressures on the flexural strength of wood waste boards

The experimental wood waste boards prepared from the dry ground Douglas-fir wood fiber showed a very marked increase in flexural strength with increase in liquid resin content of treated fiber when the material was pressed without being dried or the volatile content resulting from the resin addition otherwise altered.

The curves in Figure 3 indicate that the strength of the panel was nearly doubled with the increasing pressure from 200 psi. to 400 psi. when the resin solids content did not exceed about 8.6 percent. At resin solids content below 4.3 percent the factor of strength increase with pressure increase from 200 psi. to 400 psi. was greater than 2, decreasing to about 1.6 at the high resin solids content.

Effect of resin content and pressure on water uptake and swelling

Figure 4 has two curves, one at 200 psi., the other at 400 psi., showing the effect of resin content (when added as a liquid resin) on the water uptake of the panels made from Douglas-fir fiber pressed without alteration of the volatile content of the material resulting from the resin addition. The water uptake is greatly reduced by small increases in resin content at the lower resin concentrations with the effect becoming less pronounced with increase in resin content. Panels pressed at 400 psi. showed approximately one-half the water uptake of panels having the same resin content but pressed at 200 psi.

The same remarks can be made about panel swelling, as can be seen in Figure 5.

Effect of volatile content on pressing time and flexural strength

Figure 6 shows a pressing time study made on panels having the same resin content but different volatile contents of 14.6 percent, 25.0 percent and 42.7 percent. Pressure used was 200 psi. and temperature 300° F. Resin solids content was 4.3 percent based on oven-dry fiber. Pressing times in minutes are plotted against flexural strengths. These curves clearly show that higher volatile contents require longer pressing times. The flexural strengths at all levels of volatile contents rapidly increase to a maximum, and then level out. The point at which they level can be considered the minimum pressing time required for that particular condition. Extra pressing times beyond the leveling off point within the limits studied do not appear to add any further increase in strength. This graph shows too an increase in flexural strength at the same resin solids content with increase in volatile content.

Effect of temperature on pressing time

Figure 7 shows a pressing time study on panels made under exactly the same conditions with the variation being temperature. Panels were made using 11.2 percent resin solids, and pressure of 200 psi. Pressing time in minutes is plotted against flexural strength at two temperatures, 300° F. and 350°F. The obvious fact, of course, is that the 350° F. temperature has shortened the pressing time. The increase in flexural strength at 350° F. is more rapid than the flexural strength increase at 300° F. It is interesting to note, however, that within the limits of this study, no appreciable difference is obtained in final ultimate flexural strength at the two temperatures. Production, of course, is vitally interested in short pressing cycles.

Effect of volatile content on density, flexural strength, tensile strength, percent water uptake and percent swelling

Figure 8 covers a study made on the physical properties of hardboard as affected by volatile content. All panels used in this study contained 4.3 percent resin solids and were pressed at 200 psi. and 300° F. Pressing time was sufficient to effect cure of resin. The volatile content was varied, and plotted versus density, flexural strength, percent water uptake and percent swelling. Let us take first the density curve. At 7.55 percent volatile content the board produced had a density of 0.62. As the volatile content increases, note that the density increases quite rapidly, then more slowly, until a crest of approximately .96 is reached at a volatile content of approximately 35 percent. The density gradually decreases again and levels off. The flexural strength curve closely parallels the density curve. The strength is low at a volatile content of 7.55 percent, rises sharply in the 8 to 15 percent range, increases more gradually to a maximum of 4,410 psi. at a volatile content of approximately 35 percent, then tapers off, falling a little more rapidly than the density curve as the higher volatile contents are used.

The tensile strength curve is similar. Optimum strengths are obtained around a volatile content of 35 percent.

The percent water uptake curve and the percent swelling curve show high values at low

volatile contents, produce minimum values at a volatile content of 35 percent, and increase again at higher volatile contents.

Every physical property studied shows optimum properties in the 30 to 40 percent range. While it is true that these properties are interdependent, the fact still remains that with this fiber and this resin at 43 percent resin solids, optimum properties are obtained at around 35 percent volatile content, which is very near to the normal fiber saturation point. A possible explanation for the observed physical properties, though not confirmed by direct experimental evidence, may be that as the volatile content is increased from the lower values, moisture and resin act as plasticizing materials, resulting i n a more dense and hard material. As moisture is further increased, it may result in a tendency for the resin to penetrate too far into the fiber interior leaving less resin to form the bond. Finally, as the moisture content becomes high enough for water to be squeezed out of the press, there may ba a "washing" of the resin out of the fiber mass, producing boards of poorer quality.

It is recognized, of course, that it may not be commercially possible to manufacture a smooth two-side board of this type at volatile contents of 30 to 40 percent to obtain optimum properties because of the danger of blows and also because of the increase in pressing times required with increase in volatile content. The manufacturer may be forced to operate in a volatile content range somewhat below the range that would give optimum properties. He will try to improve properties by other means, such as: Use of high and low pressures in the pressing cycle, use of waxes or other sizing materials to improve water uptake and water swelling performance, use of different type fibers, etc.

Any research paper always leads to new avenues of investigation, and Monsanto is carrying on this work with increased emphasis on studies of actual manufacturing operations in cooperation with hardboard and wood waste product manufacturers.

EXPERIMENTAL

Wood waste panels were produced in the laboratory under a wide range of conditions to determine the effects of variables on the properties of the resultant board. In this study, dry ground Douglas-fir fiber produced by grinding hogged wood in an Allis Chalmers interplane grinder, was used exclusively. The fiber was screened to remove material passing through a 60-mesh screen.

The resin used as a binder for the fiber was Lab. No. 2469, a 43 percent-resin-solids, liquid, phenolic possessing good flow properties. It was added by spraying into tumbling fiber.

All laboratory test panels were smooth two-side panels and measured 6-3/4 inches by 10 inches by 1/4 inch.

In the study of the effect of resin content on the properties of the panels, two series of panels were prepared having resin contents of 2.2 percent, 4.4 percent, 6.6 percent, 8.8 percent and 13.6 percent based on bone dry fiber. To obtain these resin solids, 5.14 percent, 10.25 percent, 15.4 percent, 20.5 percent and 31.6 percent of Lab. No. 2469 resin based on bone dry fiber, was added. One series was pressed at 200 psi. and the other pressed at 400 psi. The fiber was at air equilibrium moisture content of 12.5 percent oven-dry basis, when treated with the resin and was pressed without prior drying or other alteration of the volatile content resulting from the resin application.

In the study of the effect of moisture content of the fiber on the properties of the panels a series of panels were produced from the dry ground fiber in which the amount of moisture at the time of treatment with resin was varied from near oven dry to over 100 percent. The air dried wood fiber was sprayed with water to give the desired moisture content and then sealed in glass jars for about a week to allow uniform moisture distribution and equilibrium to be reached. Additional fiber was oven dried to near bone dry and a portion of this material was sprayed with water to give a moisture content intermediate between the dry fiber and that at air equilibrium. Each batch of fiber was sprayed with Lab. No. 2469 resin at the rate of 4.3 parts resin solids per 100 parts bone dry fiber. To obtain this 4.3 parts resin solids, 10 parts of the liquid Lab. No. 2469 resin were added.

The panels were pressed at 200 psi. at 300° F. with the pressing time being varied to allow for the variation in the moisture content but being held long enough to insure complete cure of the resin. The moisture content of the fiber just prior to the resin treatment and the volatile content of the material just prior to pressing were determined by oven drying.

For the purpose of studying the pressing time requirements of 1/4 inch panels produced from the Douglas-fir fiber, three series of panels were prepared from fiber at volatile contents of 42 percent, 25 percent and 14 percent oven dry basis, with 4.3 parts resin solids,

(10 parts Lab. No. 2469 liquid resin per 100 parts oven dry fiber). All panels were pressed at 200 psi. and at 300° F. The panels were pressed for varying lengths of time from that which resulted in "blows" to times in excess of that considered sufficient for complete cure of the resin.

Two additional series for pressing time study were prepared at temperatures of 300° F. and 350° F. with the fiber at a volatile content of about 20 percent to 25 percent and at an 11.2 percent resin solids content.

The properties determined for evaluation of the various panels were density, flexural and tensile strengths, and the amount of swelling and water uptake resulting from soaking in water at 80° F. for 24 hours. The method of preparing the test specimens and the test methods were as follows:

TEST METHODS

Moisture and Volatile Determinations

Representative samples of the fiber weighing 10 to 15 grams were weighed to the nearest 0.01 gram and placed in an oven at 220° F. overnight. After removal from the oven, the samples were cooled in a desiccator over phosphoric oxide and reweighed. The percent moisture or volatile content was calculated from the weight loss as a percentage of the oven dry weight.

Flexural and Tensile Strength:

Samples were cut from the experimental panels to provide three one-inch strips transverse across one end of the panel and six 1-inch by 4-1/2 inch strips longitudinally across the opposite end. The flexural strength determinations were made using an adapter for a Model J-2 Scott tester in which the span for breaking the specimen was 3.00 inch with the load being applied at mid-span with a head speed of 4 in./min. Breaks were made on all nine specimens from each panel.

Each half of the three transverse specimens were used for the determination of tensile strength using the Model J-2 Scott tester.

The flexural strength in psi. was calculated from the following formula:

$$S = \frac{(6)\ (\text{Load})\ (\text{Span})}{(4)\ (\text{Width})\ (\text{Thickness})^2}$$

Load in pounds; span, width, and thickness in inches.

The tensile strength in psi. was calculated from the following formula:

$$S = \frac{(\text{Load})}{(\text{Width})\ (\text{Thickness})}$$

Load in pounds; width and thickness in inches.

Density:

The density of the panels was determined by calculation from the weight and measurements. The density was determined not less than one day after the panel was made.

Water Uptake and Swelling:

Specimens for the determination of water uptake and swelling were 1-5/8 inch square pieces cut in duplicate from the center of the panel. The specimens were placed in a conditioning cabinet at 58 percent relative humidity and 80° F. for five days before testing. Each sample was weighed to the nearest 0.01 gram and the thickness and length determined by a micrometer caliper. The specimen was then totally immersed in a soaking tank in which the temperature of the water was thermostatically controlled at 80° F. The specimens were allowed to soak exactly 24 hours. The samples were then removed from the tank, blotted on a towel, weighed and the measurements again taken at the same spot as originally. The changes in weight and dimensions were determined and the percent change calculated on the basis of the original weight and measurements after conditioning.

Figure 2

THE EFFECT OF RESIN CONTENT ON THE DENSITY OF WOOD WASTE BOARDS PRODUCED FROM DRY GROUND DOUGLAS FIR WITH LAB. NO. 2469 RESIN
Panels 6-3/4" x 10" Pressed at 200 and 400 psi at 300° F.

% Resin Solids	Density 200 psi	Density 400 psi
2.2	0.774	0.951
4.4	0.825	0.992
6.6	0.897	1.060
8.8	0.916	1.090
13.6	0.950	1.175

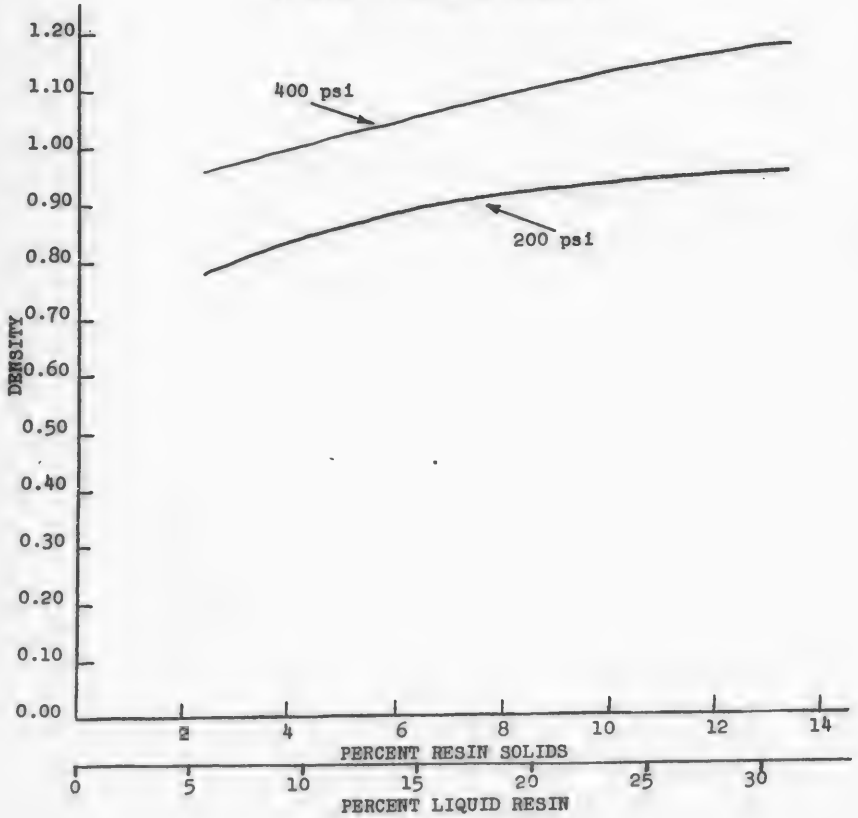


Figure 1

THE EFFECT OF THE SPRAY ADDITION OF LAB. NO. 2469 RESIN ON THE VOLATILE CONTENT OF DRY GROUND DOUGLAS FIR FIBER HAVING A MOISTURE CONTENT OF 12.5% BASED ON WEIGHT WHEN DRY

Percent Resin	Percent Volatile
0.0	12.5
5.14	12.8
10.25	15.6
15.4	16.8
20.5	18.3
31.6	22.5

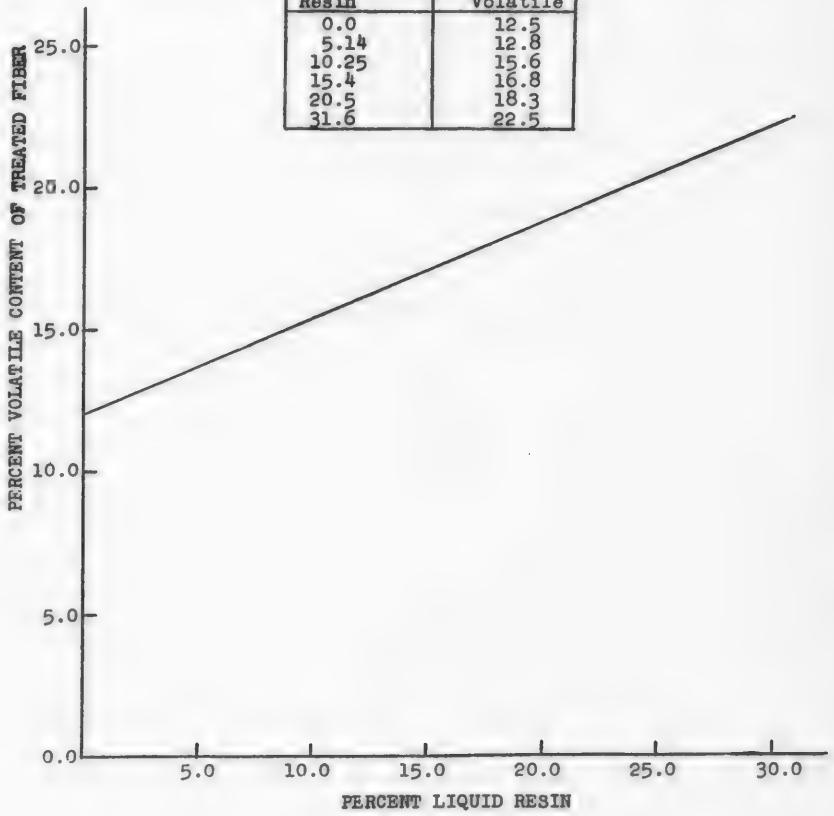


Figure 3

THE EFFECT OF RESIN CONTENT ON THE FLEXURAL STRENGTH OF WOOD WASTE BOARDS PRODUCED FROM DRY GROUND DOUGLAS FIR WITH LAB. NO. 2469 RESIN
Panels 6-3/4" x 10" Pressed at 200 and 400 psi at 300° F.

% Resin Solids	Flexural Strength	
	200 psi	400 psi
2.2	1110	2500
4.4	2000	4260
6.6	3110	5700
8.8	3550	5930
13.6	4650	7560

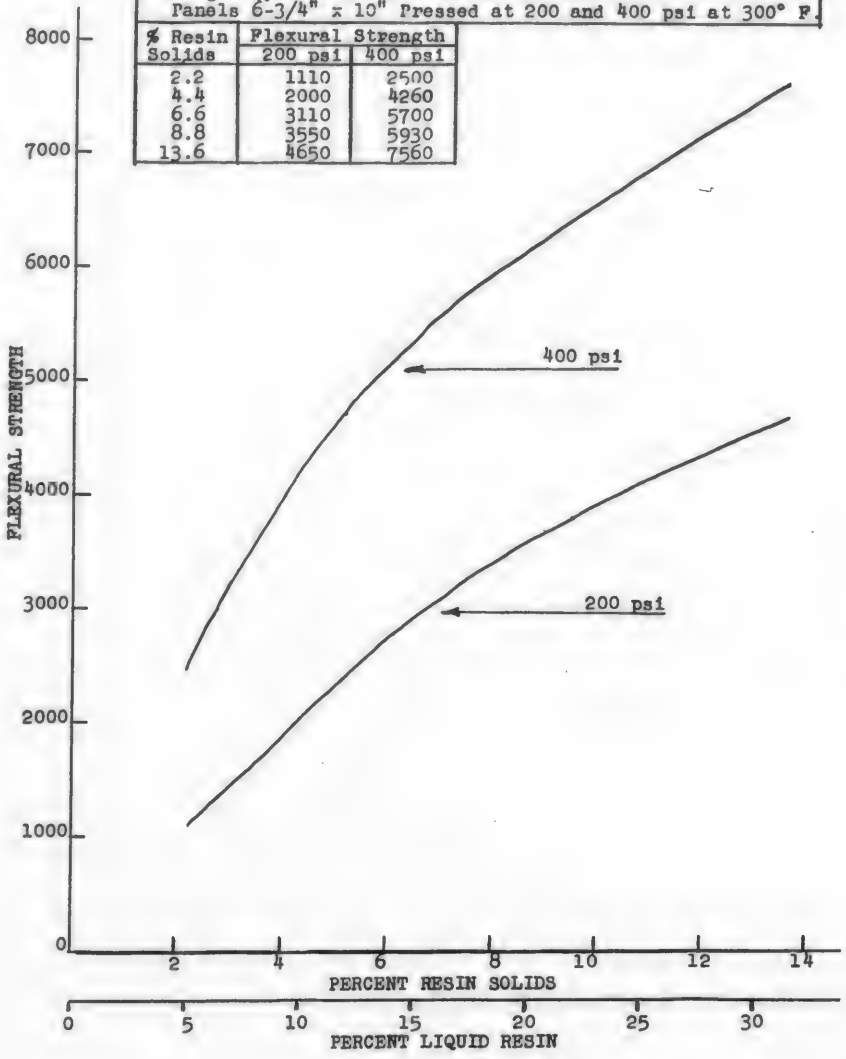


Figure 4

THE EFFECT OF RESIN CONTENT ON THE WATER UPTAKE OF WOOD WASTE BOARDS PRODUCED FROM DRY GROUND DOUGLAS FIR WITH LAB. NO. 2469 RESIN WHEN SOAKED 24 HOURS AT 80° F.
Panels 6-3/4" x 10" Pressed at 200 and 400 psi at 300° F.

% Resin Solids	% Water Uptake	
	200 psi	400 psi
2.2	112	49.6
4.4	72.4	29.4
6.6	41.2	17.7
8.8	41.3	11.5
13.6	18.2	5.3

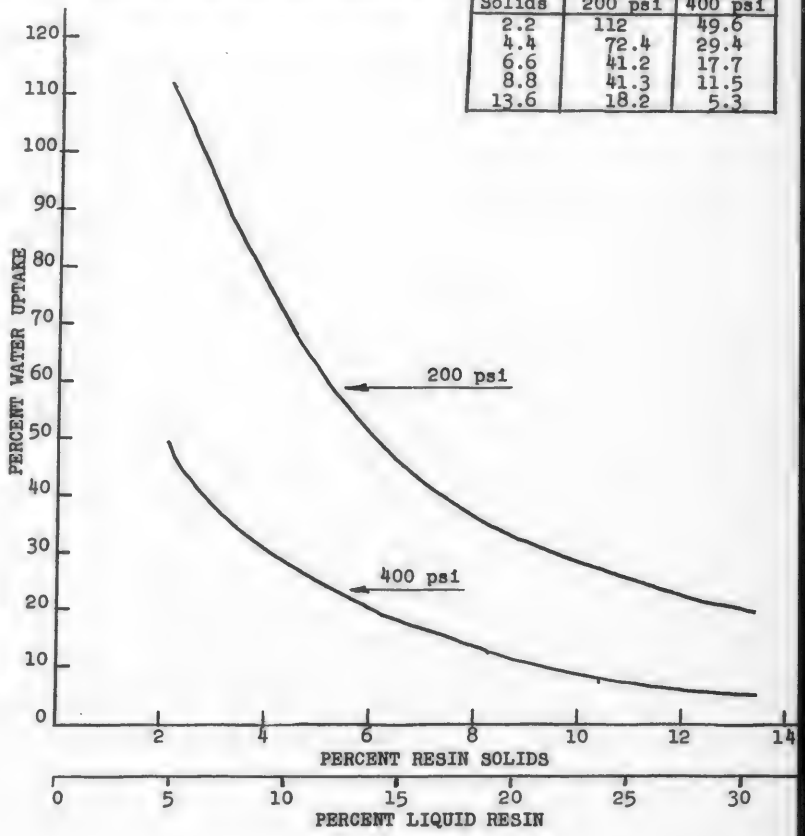


Figure 5

THE EFFECT OF RESIN CONTENT ON THE SWELLING OF WOOD WASTE BOARDS PRODUCED FROM DRY GROUND DOUGLAS FIR WITH LAB. NO. 2469 RESIN WHEN SOAKED 24 HOURS AT 80° F.
Panels 6-3/4" x 10" Pressed at 200 and 400 psi at 300° F.

% Resin Solids	% Swelling 200 psi	400 psi
2.2	47.1	27.2
4.4	25.5	13.0
6.6	17.1	6.7
8.8	15.4	5.6
13.6	6.8	2.7

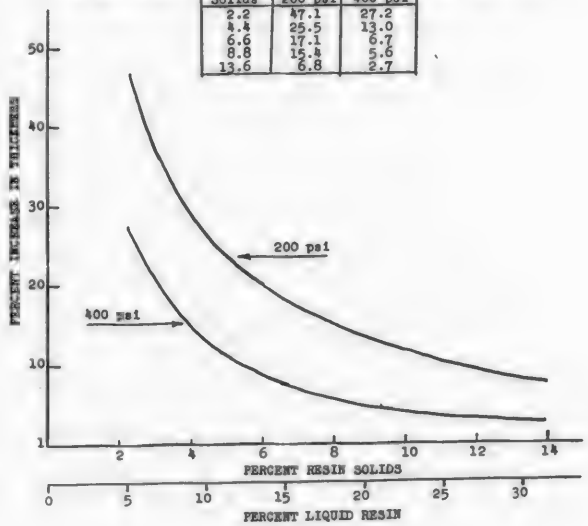


Figure 7

PRESSING TIME SERIES FOR 1/4" WOOD WASTE BOARDS PRODUCED FROM DRY GROUND DOUGLAS FIR FIBER WITH 11.2% RESIN SOLIDS LAB. NO. 2469
Panels 6-3/4" x 10" Pressed at 200 psi. and at 300° and 350° F.

T.P.	Flexural Strength 300° F.	350° F.
3		1170
3½		3250
4	1020	3930
4½	1260	4435
5	2140	4090
5½	3830	4730
6	3820	4135
6½	4240	4410
7	4510	4330
7½	4280	
8	4550	

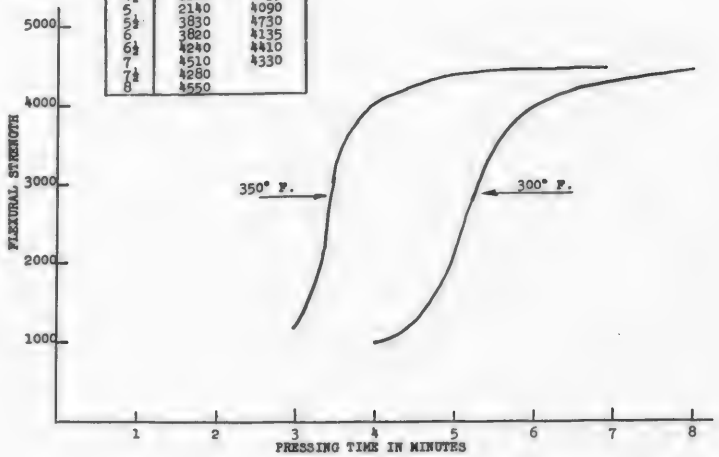


Figure 6

PRESSING TIME SERIES FOR 1/4" WOOD WASTE BOARDS PRODUCED FROM DRY GROUND DOUGLAS FIR WITH 4.3% SOLIDS USING LAB. NO. 2469 RESIN. PANELS 6-3/4" x 10" PRESSED AT 200 psi. and 300° F. From Fiber Having Volatile Contents of 14.6%, 25.0% and 42.7%.

14.6% Volatile T.P.	Flexural Strength	25.0% Volatile T.P.	Flexural Strength	42.7% Volatile T.A.	Flexural Strength
3	617	5	632	10	2190
3½	822	6	1810	11	2800
4	930	6½	1950	12	3240
4½	905	7	2200	12	3180
5	991	8	2180	13	3450
5½	740	9	2210	14	3460
6	919	10	2510	15	2740
6½	1010	11	2250	17	3030
7	1020	12	2130	19	3510
7½	881	13	2300		
8	1020	14	2370		
		15	2280		

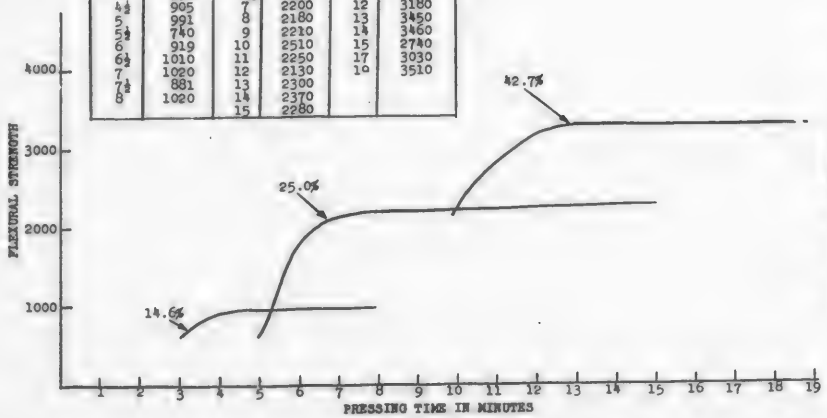
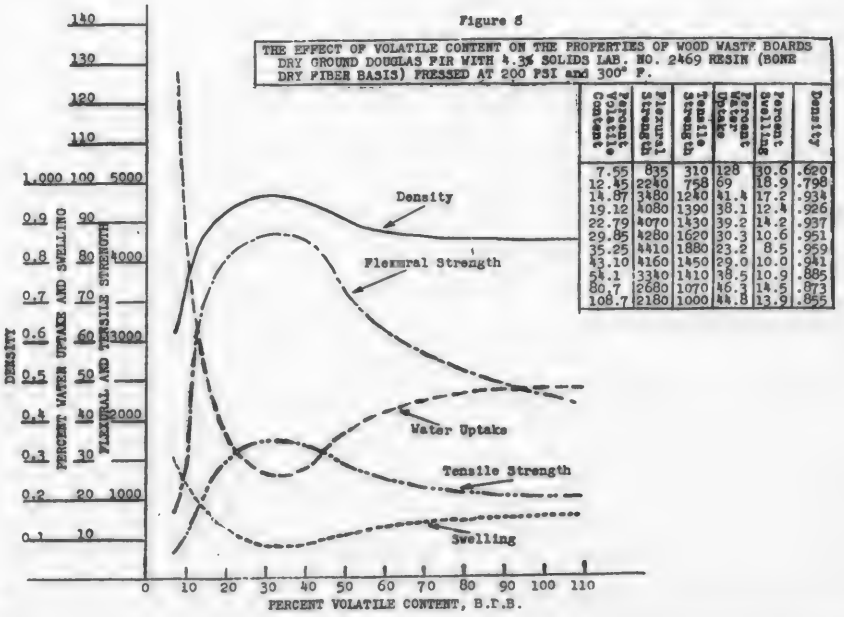


Figure 8

THE EFFECT OF VOLATILE CONTENT ON THE PROPERTIES OF WOOD WASTE BOARDS DRY GROUND DOUGLAS FIR WITH 4.3% SOLIDS LAB. NO. 2469 RESIN (BONE DRY FIBER BASIS) PRESSED AT 200 PSI and 300° F.

Percent Volatile Content	Flexural Strength	Tensile Strength	Percent Water Uptake	Percent Swelling	Density
7.55	835	310	128	30.6	.620
12.45	2240	758	69	18.9	.798
14.87	3480	1240	41.4	17.2	.934
19.12	4080	1390	38.1	12.4	.926
22.79	4070	1430	39.2	14.2	.937
29.85	4280	1620	30.3	10.6	.951
35.25	4410	1880	23.2	8.5	.959
43.10	4160	1450	29.0	10.0	.941
54.1	3340	1410	38.5	10.9	.885
80.7	2680	1070	46.3	14.5	.873
108.7	2180	1000	44.8	13.9	.855



JOURNAL of the FOREST PRODUCTS RESEARCH SOCIETY

Mechanical Equipment For Fiberizing Wood[1]

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To do justice to this subject in a short paper is impossible, but we can present some of the basic fundamentals involved so that regardless of whether you know much or little about this particular field, you can have some understanding of its basic elements. The subject is presented in four parts indicated by the headings.

PART 1
WOOD AND THE IMPORTANCE OF PROPER PREPARATION AHEAD OF FIBERIZING

We know that wood is a hard dense material of many types and species, each with its own fundamental structure. It is composed of cellulose fibers of very minute diameters and lengths, tightly held together with binding agents such as lignin and other chemicals. Using wood in the pulp and paper industry, therefore, involves breaking it apart or separating it into some kind of a fibrous mass that we can utilize. Now, whether the breaking apart of wood is called fiberizing, de-fiberizing, or refining makes no difference. What we are looking for are fibers that can be used in our end product. We are not necessarily talking about individual fibers but bundles of fibers and how to obtain them by mechanical means.

The problem is to take this large, hard, dense, compact mass of wood and get it into a form where we can break it down mechanically into fibers. Three methods present themselves. One of these is by size reduction of the raw material, the second is by cooking, and the third is by the use of chemicals. The first is obvious as we have to take the tree and break it down by sawing, hogging, chipping, etc. to a size that can be used and then further on down to a fibrous mass. In the second method, cooking, it is obvious that if we take any vegetable matter, including wood, and subject it to high enough temperature for a long enough period of time, certain of the binding agents will soften, thus freeing the fiber. The third method is to add certain chemicals to the wood that will react with the binding agents and free the fibers or bundles of fibers.

Thus, pulp and paper operations involve size reduction, cooking, which we call digesting, and the use of chemicals. All three can be carried along to a greater or lesser extent depending upon what we want to do. If we produce chips, cook, and apply chemicals to such chips without the use of any further mechanical equipment, our end product will be dissolving pulp, used as a raw material in the production or rayon and cellophane, where all of the miscellaneous material in the wood is cooked and dissolved away from the true cellulose fibers. If we carry it only part way, we have semi-chemical pulp and we utilize mechanical means to help us after the material is partially softened. If we use no chemicals and apply merely steam heat to the wood chips, we can soften the wood to the point where we can apply mechanical work to the stock to produce a fiber suitable for such end items as roofing felt, insulating board, etc. If we use no cooking and no chemicals and grind the log down with a stone, we have straight mechanically produced groundwood stock.

Therefore, bear in mind that the preparation of the wood ahead of any kind of mechanical equipment is extremely important in this business of producing a fiber from a wood product.

PART 2
TYPES AND PRINCIPLES OF WOOD FIBERIZING EQUIPMENT

In studying some of the elemental types of mechanical force used on wood stock to produce fiber, we are primarily dealing with equipment that is used to "make little ones out of big ones". In other words, we are in the size reduction field, and we find the same basic pieces of equipment are being used elsewhere in other process industries for size reduction. The machines involved fall into the two basic classifications of batch and continuous machines. We'll first discuss batch operations.

A. Batch Equipment

We'll briefly touch on three basic types of batch equipment.

1. Tanks with high speed impellers.
   Here we are talking about essentially tanks of various shapes and sizes. See Figure 1A. These tanks usually have one or more impellers to provide high speed agitation of the material in the tank. Cooked or partially cooked or partially fiberized wood plus water circulates rapidly past high speed im-

[1] Presented at Meeting of Forest Products Research Society, Northern California Section, San Francisco, California, May 9, 1952.

pellers, causing a breakdown of the individual particles to some smaller state. You can simulate the action of most of these batch units in the "Waring Blendor" that you may use at home. There are many unique pieces of equipment on the market with various arrangements for doing this job, such as the "Cowles Aqua Pulper", the "Morden" 'Slush Maker' Pulper", the "E. D. Jones Pulpmaster", and the "Rice Barton Quatro Pulper" and "DynoPulper".

2. Beaters.
   The conventional beater, as shown in Figure 1B, is another elemental type of machine. The beater is essentially a vessel in which the stock moves continuously around an elongated doughnut shaped tank, passing at every revolution under a beating roll where the the stock is beaten and rubbed between the rotating roll and a stationary section.

3. Ball Mills and Rod Mills.
   Batch equipment of the ball mill and rod mill type, as shown in Figure 1C, has been used for breaking down wood. The ball mill or rod mill in principle is a heavy, slowly rotating, cylindrical tank in which heavy balls of metal or porcelain or rods of metal or other materials keep up a continous cascading action as the shell rotates. A softened or cooked wood with water in such a unit would gradually break down by the crushing action of the rods or balls into a pulpy mass.

4. Pan Mill.
   The "Kollergang Refiner" is an example of the common pan mill or edge runner used for breaking down wood to fiber. See Figure 1D. This is a very old method of size reduction.

In most operations, the economics are such that continuous equipment of one kind or another is being used, but some of these essentially batch units are also employed as continuous units.

B. Continuous Equipment

1. Disc or Attrition Mills.
   The disc mills, as shown in Figures 2A and 2B, are probably the most common pieces of mechanical equipment being used today in this general field of wood fiberizing. Disc mills, or as they are commonly called, attrition mills, use a principle of size reduction that has been employed by man for thousands of years. Essentially, they consist of two discs in a vertical or horizontal plane. Either one or both of these discs rotate. They are made of either metal or stone. The old buhr stone mill used back in the days of George Washington for making flour was a stone disc-type mill. The material is usually fed into the center through one disc and passes out between the two stones or discs to the outside. Usually, the clearance between the two plates is manually adjusted. This varies the amount of work that will be done on the material while it is in the unit. They are built in various diameters and for operating at various speeds. Material may flow in by gravity or be pumped in under pressure. They are available in sizes ranging from small laboratory models up to units employing hundreds of horsepower. Any material that is fed in between these two plates will be rolled and rubbed and broken by attrition and by impact between the plates and the particles themselves and will reduce in size. Wood passing through disc mills will come out in a more or less broken-down state, depending upon how it was prepared, the speed at which the mill is operated, the design of the plate surfaces, and the amount of water or the consistency of the stock that comes in. Because of the small clearance between the plates, the size of particle that can be admitted is limited. Wear is a factor because the characteristics of the finished product will depend on the sharpness of the steel or stone plates. Some of the more common disc type mills include:
   a) The "Bauer Pulp Refiner", a double disc attrition mill, available in several different sizes and with horsepowers up to 600. Bauer also makes a small single revolving-disc pulp refiner for laboratory work.
   b) The "Sprout-Waldron Refiner" for continuous beating and refining is fundamentally a single rotating disc refiner, available in several different sizes.
   c) The "Sutherland Refiner" for continuous beating and refining is fundamentally a single rotating disc refiner, available in several different sizes.

d) The "Allis Chalmers Inter-Plane Grinder" is a vertical disc mill of unique characteristics.
e) The "Asplund" single-disc fiberizing unit is used often in conjunction with a continuous-screw type pressure cooker for handling the cooking and fiberizing operation on wood chips or hogged wood.

2. The Cone or Plug Refiner.
The cone or plug type of fiberizer or refiner as shown in Figure 2C is most commonly represented by the conventional Jordan, which has been used for many services in the pulp and paper industry. The principle of operation of the cone or plug type of unit and the disc type is quite similar. In the case of this entire group of machines, we have a rotating cone-shaped plug inside a stationary cone. The stock is admitted at one end, passes through the space between the two cones and discharges at the other end. Here again, the arrangements of the surfaces, the speed of operation and the diameter of the machine influence what that machine will do. On the conventional Jordans, which are written up in most of the paper mill literature, the angle of the cone is fairly small and the clearances between the rotating and the stationary plates are very small; thus, we have a machine which is usually considered as a cutting device. Such machines are generally not used in the field of wood fiberizing However, many modifications of this principle have been brought out, involving greater clearances between the rotating and the stationary section and involving steeper angles, where these machines do more of a wood fiberizing job. In this field we have:
a) The "Hermann Claflin" used as a continuous beater and refiner.
b) The Shartles Brothers "Hydrafiner", a similar machine used for hydrating, brushing, fibrolizing, or any one of the other names that you might want to give this type of wood reduction.
c) The "Morden Stock Maker" is a versatile machine, doing what is generally known as refining or beating.

3. Hammer Mills.
Here we are talking about another type of size-reduction equipment that has been used for breaking down wood. See Figure 2D. These are called hammer mills or shredders. Such machines as the Gruendler and the Williams hammer mill and the Jeffrey shredder consist of a horizontal shaft with hammers partially surrounded by a screen plate in the bottom. The high speed action of the rotor beating against the material as it comes in, usually in the presence of water, will beat and tear the wood apart and discharge it through the perforated screen.

4. Special Machines.
There are a number of special machines that have been used, which have somewhat the same elemental features as discussed above, arranged in different mechanical ways.
a) One of these is the "Noble-Wood Mill". It is fundamentally a rotating cylinder running in close apposition to a stationary cylinder. Stock is fed in against this rotating cylinder, and passes between the rotating surface and the stationary surface, being reduced and rolled and rubbed as it passes through the machine. It is advertised as a large scale development of the colloid principle of high speed rubbing or fluid shear. In effect, a colloid mill is a mill with a stationary housing and a rotating disc where extremely close clearances between the rotor and the stator are maintained.
b) The "Rietz Disintegrator" shown in Figure 2E is another specialty machine used for fiberizing stock. In principle, it is a vertical shaft, on which are fixed hammers. Surrounding these hammers is a full 360° screen. Close clearance is maintained between the ends of the hammers and the screens, although this clearance is not adjustable as it is in the disc mills or the cone type mills. Due to this clearance, there is little cutting action within the unit. Stock is reduced by attrition against the stationary surface, and against the particles in the presence of water at medium consistencies, and is discharged through the screen plates. One feature of the Rietz Disintegrator is the possibility of letting oversized disintegration-resistant stock pass out below the rotor for recycling or rejection.

c) We'll mention under special equipment, although it is a standard piece of equipment, the groundwood grinding units, which are essentially large grindstones with mechanisms to hold the wood against the grindstone and mechanisms for spraying a controlled amount of water against the stone while the grinding action takes place. See Figure 2F for the principles of operations. The "Roberts Grinder" manufactured by Appleton Machine Company is a typical example of these types of pulpwood grinders. To give you an idea of the sizes and scopes of these machines, on one of the Roberts Grinders, they can use up to 3,000 hp. at 225 to 300 rpm. with a stone of 62 inches in diameter with a 54-inch face.

d) Another specialty machine is the Apmew Hydrator-Digester-Pulper-Refiner, a horizontal machine doing both cooking and defiberizing in the same unit.

e) The "Curlator" is a new special-type of machine. Its action is similar to that of a vertical disc mill but it has a number of innovations which time will not permit discussing.

PART 3
IMPORTANT FACTORS IN THE USE OF MECHANICAL FIBERIZING EQUIPMENT

Bearing some of these principles in mind, let's briefly mention some of the factors involved in getting a proper product from the machines described above.

A. Type of wood is always important. Under a particular set of conditions, one type of wood may fiberize well in one machine and another type of wood would be a miserable failure.

B. Keep in mind always the importance of (a) breaking down the whole log to a particle size that can be properly handled, (b) the matter of the cooking times and temperatures and (c) the matter of the chemicals that are used. All of these things influence the performance of a given mechanical fiberizer.

C. In the specific types of machines used, there are many variables inherent in the machine itself. Such factors as speed, arrangement of the plates, clearance, other adjustments that can be made to the machine itself, all will influence what that machine does. Many times, very small changes in adjustment, which do not seem important at all, will greatly change what a given machine will do under a given set of circumstances.

D. On many of these pieces of machinery, it is important that auxiliary equipment used ahead of that machine be properly applied. Will that machine take stock in under pressure, and, if so, how much pressure? How is the flow of stock, whereas on others it makes no difference. What is the consistency of the stock? On some machines, under one set of circumstances, a low consistency will be required. What do the wear factors have to do with the operation of the machine? What is the proper speed? All of these things are important in getting the most out of a given machine and they all have to do with the tremendous mass of know-how developed by the machinery manufacturers and by the operators in making that machine do a satisfactory job.

E. The matter of taking the stock away from mechanical fiberizing devices is important. Some machines operate best when the material is in the machine under pressure. Others need a free discharge. On some machines, you can use gravity flow from the machine and on others you must use pumps. Has the pump sufficient capacity to take away the stock? I saw an example of the importance of proper discharge in an application of a Rietz Disintegrator several months ago, where a 40 hp. motor on a small screen reject operation with a normal full-load demand of 50 amps. was drawing 100 amps. Stock from the disintegrator was going into a large centrifugal pump. Obviously, something was wrong -- as evidenced by the high amperage being drawn for the amount of stock it was handling. One of the first things we noticed was that the machine was filling up with stock indicating that the pump was not taking away the stock as fast as it was going through the machine. The mill operators were convinced that the capacity of the pump was 3 to 4 times greater than the flow of material into it. It took a little persuasion to get them to disconnect the pump and let the stock flow out on the floor. Sure enough, just as soon as the pump was disconnected and the stock allowed to flow freely away from the machine, the amperage dropped from 100 amps. down to 30 amps. In this particular case, it was not the disintegrator nor was it the pump that was the culprit. It was air. The pump was getting air-bound and, consequently, not keeping up with the load in spite of the fact that its rated capacity was far greater than that required. The obvious solution was to dump the stock into a box and pump from the bottom of the box, where a constant head could be maintained on the pump.

F. In any kind of an economical operation in wood defiberizing, other auxiliary equipment becomes important, for instance, screening. There's a good deal of historical precedent for using screens or some kind of separation device in conjunction with size reduction devices. If you can use screens to remove the desired material from a given stock and employ the reduction unit only on the oversize material, oftentimes substantial savings in equipment and power can be realized. This applies in the wood fiberizing field to a much less extent than it does for paper pulp.

G. Evaluation of results on any particular type of installation is important. Standard laboratory tests can be used such as fiber classification tests, strength tests, tear tests, visual inspection, etc.

PART 4
THE FUTURE PROSPECTS FOR MECHANICAL WOOD FIBERIZING

In general, the trend is in two directions.

A. Increasing the utilization of wood, particularly refuse wood, in producing some kind of a usable end product.

B. Increasing the yield of the wood that is used.

The amount of wood waste, as you know, is enormous. There are many types of woods that have never been utilized previously for pulping of any kind. On the other hand, there is an increasing market for many types of wood pulp products such as building materials, paper products used for shipping containers, insulation materials, etc. It is these low cost fiberizing systems that will make the utilization of the waste wood products possible. Pressed hardboards are being produced in increasing quantities. Soft insulating boards for sound deadening purposes, for interior walls, etc., are being more and more used. The raw materials used for these products have heretofore been wasted. Fairly inexpensive processing methods must be used in order to make such products cheap enough to sell in the competitive markets that exist.

With the shortage of wood, it becomes increasingly important that higher yields be obtained. After all, we can take this wood and, by the use of digestion and chemical means, we can virtually take all of the binding lignin, etc. away from the wood fiber, leaving the cellulose component only for making into the paper or board end products, but our yield is low. On the other hand, if we can prepare the material and make just as good a finished product by leaving most of the original constituents of the wood in the finished product we will get more pounds of finished product from the pounds of wood that we start with. Thus, today we're getting 70 percent, 80 percent and 90 percent yields from some woods in place of the 40 percent to 60 percent that we used to get. It is obvious that we cannot use these high yield stocks for all types of end products, but we can use them for many.

LITERATURE REFERENCES

1) Paper and Pulp Mill Catalog, "Engineering Handbook". 1951. 1952. Fritz Publications, Inc.

2) Pulp and Paper Manufacture, Vol. 1 - Preparation and Treatment of Wood Pulp, 1950. McGraw-Hill Publishing Company. J. Newell Stephenson, Editor-in-Chief.

3) Pulp and Paper Manufacture, Vol. 2 - Preparation of Stock for Paper Making, 1951. McGraw-Hill Publishing Company. J. Newell Stephenson, Editor-in-Chief.

4) Witham, G. S. Jr. Modern Pulp and Paper Making, 2nd Edition 1942. Reinhold Publishing Corp.

Manufacturers' catalogs as follows:

Allis Chalmers Mfg. Co.
"Interplane Grinder"

Apmew, Inc.
"Apmew patented Digester-Pulping-Refiner"

Appleton Machine Co.
"Roberts Grinder"
"Appleton Jordans"

The Bauer Bros. Co.
"Pulp Refiners"

Carthage Machine Co.
"Carthage Chipper"
"Carthage Wood Pulp Grinder"

The Cowles Co.
"Cowles Aquapulper"

Downingtown Mfg. Co.
"Downingtown Fibre Pulper"

The Hermann Mfg. Co.
"Hermann Claflin"

Jeffrey Mfg. Co.
"Jeffrey Shredders"

E. D. Jones & Sons Co.
"Fibremaster"
"Pulp-Master"
"Beaters and Jordans"

Morden Machines Co.
"Morden Stock-Maker"'
"Morden Slush-Maker"

The Noble & Wood Machine Co.
"The Noble-Wood Mill"

"Victory Beater"
"Jordans"
Rice Barton Research Corp.
"Rice Barton Quatro Pulper"
"Rice Barton Dyno Pulper"
"Rice Barton Dyno Finer"

Rietz Mfg. Co.
"Rietz Disintegrator"
"Rietz Prebreaker"
Shartle Bros. Machine Co.
"Hydrafiners"
"Miami Jordans"

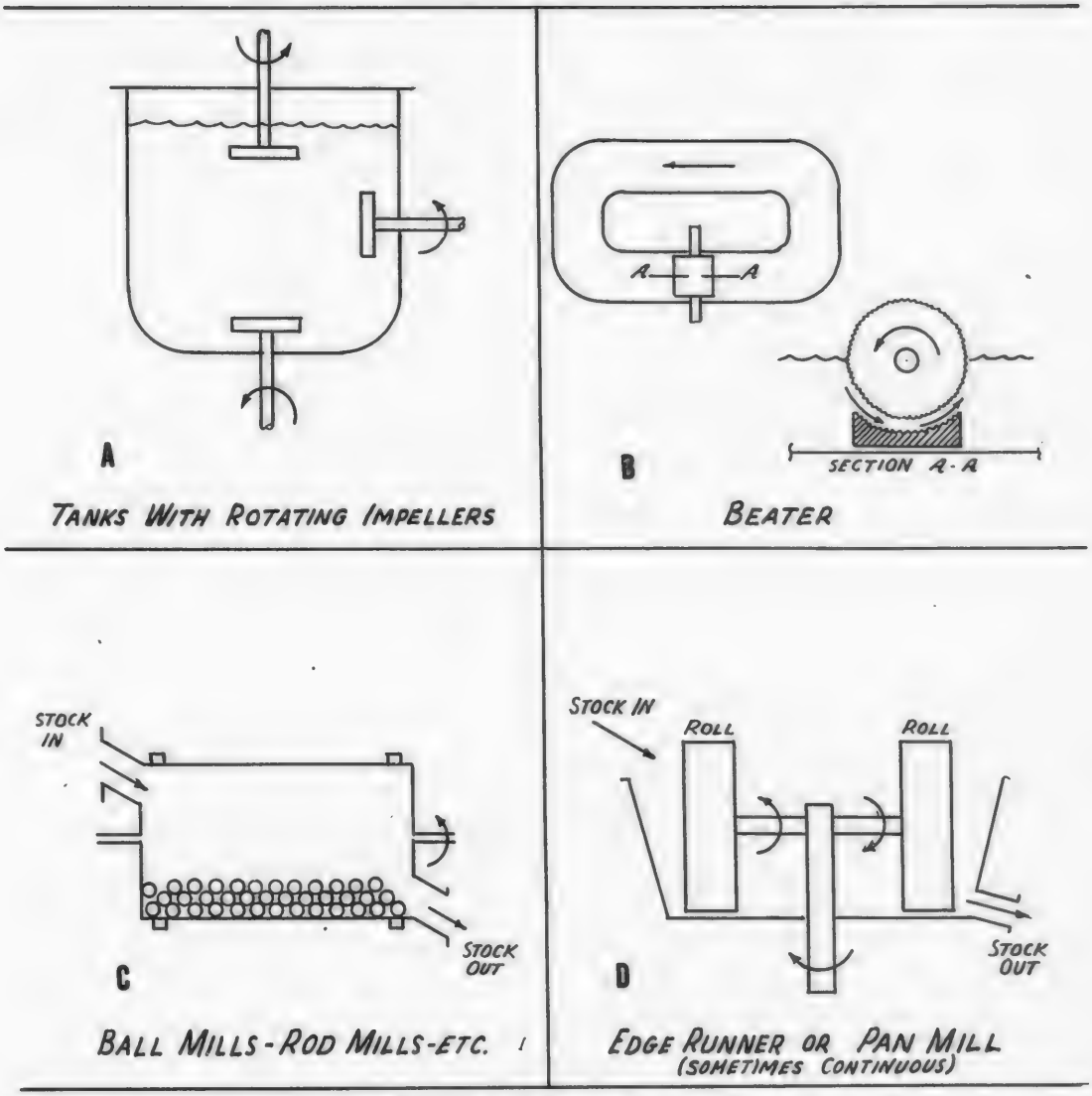

FIGURE 1. PRINCIPLES OF BATCH EQUIPMENT FOR WOOD FIBERIZING.

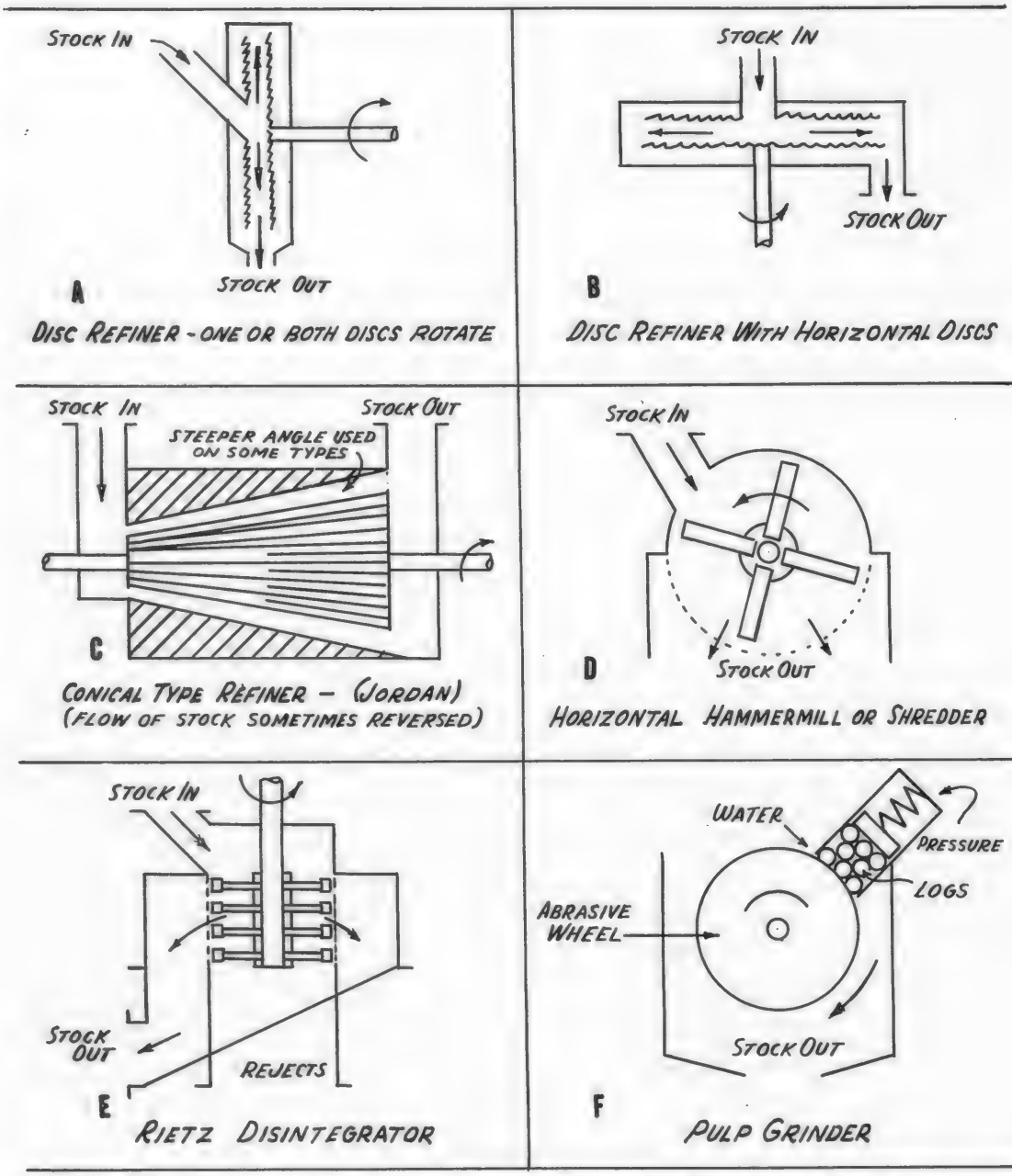

FIGURE 2. PRINCIPLES OF CONTINUOUS EQUIPMENT FOR WOOD FIBERIZING.

Practical Methods for the Control of Insects Attacking Green Logs and Lumber[1]

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SUMMARY

Investigations conducted during the period 1944 to 1951 have shown that benzene hexachloride, when properly applied, is effective in preventing attack by ambrosia beetles, bark beetles, and wood borers on green hardwood logs and lumber and on pine logs.

Protection of Logs

A concentration of sufficient benzene hexachloride to give 1-3/4 pounds of the gamma isomer per 50 gallons of No. 2 fuel oil is recommended for the prevention of attack by ambrosia beetles on hardwood and pine logs. This formulation has given good protection for 3 to 4 months during the season of heaviest beetle activity.

Wettable benzene hexachloride at a concentration of 2 pounds of the gamma isomer in 50 gallons of water has protected hardwood logs for a period of 3 or 4 months in limited tests.

Sufficient benzene hexachloride to give 7/8 pound of the gamma isomer per 50 gallons of No. 2 fuel oil is recommended for preventing attack by bark beetles on pine. Wettable benzene hexachloride at 1 pound of the gamma isomer in 50 gallons of water also has shown promising results on pine.

Each of these formulations must be applied until all bark surface is wet, or at the rate of 1 gallon per 100 square feet of bark surface. They can be applied after the logs are stacked provided proper equipment is used. (See Fig. 1.) In fact, to obtain best results from chemical treatment, logs should be stacked as high as it is possible to spray them and in long, continuous rows rather than in a number of small decks.

Protection of Lumber

An emulsion of benzene hexachloride containing 5 ounces of the gamma isomer per 50 gallons of water is recommended for preventing attack by ambrosia beetles on green hardwood lumber. It is applied by dipping in vats in conjunction with measures for preventing sap stain.

Mists and dusts of benzene hexachloride applied to stacks of lumber are also effective in preventing attack by ambrosia beetles. Considerable care must be exercised in applying them; otherwise over-dosages will result in excessive costs.

INTRODUCTION

From the time hardwood and pine trees are felled until the logs are sawed into lumber they are subject to attack by numerous species of wood borers and bark beetles. Furthermore, green hardwood lumber itself is often damaged by some of these insects.

Figure 1. Applying benzene hexachloride to stacks of red gum logs with hydraulic sprayer to prevent attack by ambrosia beetles. To obtain good results the spray must be directed into the spaces between the logs from each end, and over the tops and sides of the deck.

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[2] For many helpful suggestions and criticisms the author is indebted to R. J. Kowal, under whose direction these investigations were made. Acknowledgements are made to J. F. Coyne and R. C. Morris for the use of data drawn from their unpublished reports and to the latter and R. E. Lee for assistance rendered in the field.

Ambrosia beetles, commonly called pinhole borers, are probably responsible for the most severe damage to hardwood logs. They may also attack green hardwood lumber, particularly if the lumber yard is located in low land where the humidity is high, and sometimes even attack pine logs. The tunnels bored by these insects are open and dust-free and range from about 0.8 to 1.3 millimeters in diameter. They often may penetrate to the center of large saw logs. Attacks by these beetles can be recognized easily by the small piles of boring dust at the entrance to the tunnels. Each species of ambrosia beetles cultivates a specific fungus upon which it feeds, and certain of these fungi cause an intense black staining of the wood adjacent to the tunnels. This stain is sometimes called "grease spot" or "flag".

Several species of larger wood borers also attack hardwoods and pine. In addition, a number of bark beetles damage pine. All these insects, as well as ambrosia beetles, allow the entrance of common sap stain or blue stain and decay organisms.

The tunnels made by these various beetles and borers and the stains they introduce cause a degrade of lumber, especially high-quality stock, and result in a serious monetary loss to the lumber industry. Ideally, control consists in rapid utilization of all logs and the end-racking of hardwood lumber. Unfortunately this procedure is often uneconomical or even impossible, because many operators find it necessary to cut and store logs during the dry summer months in order to operate during the following winter, when logging is too expensive because of weather conditions. These logs are frequently stored where they are exposed to beetle attack. Furthermore, importers of logs could not possibly practice the rapid-utilization method of control. In such cases it is profitable to apply chemical control measures.

The need for chemical control of the insects under discussion has been recognized for many years, and many chemicals have been tested by Federal and private agencies, but until recently none were satisfactory.

During the period 1944 to 1951 the Gulfport, Miss., laboratory of the Bureau of Entomology and Plant Quarantine, conducted tests for the control of insects attacking green hardwood logs and lumber and green pine logs, and developed a satisfactory chemical control. These investigations included tests of most of the new insecticides and were conducted in cooperation with lumber manufacturers in Mississippi, Louisiana, Alabama, and in the Tropics. They have demonstrated that benzene hexachloride is the most effective chemical tested, and a number of manufacturers are now formulating this chemical for treatment of logs and lumber. Its effectiveness and practical application are demonstrated by the fact that it is being used widely for protection of hardwoods and pine by operators in the United States and in the Tropics.

This article points out the primary results of these investigations and offers practical suggestions for the treatment of hardwood and pine logs and hardwood lumber to prevent attack by insects.

PROTECTION OF LOGS, POLES, AND PULPWOOD

Preventive Treatments

Oil solutions. Benzene hexachloride at a concentration of 1-3/4 pounds of the gamma isomer[3] per 50 gallons of No. 2 fuel oil is recommended for use on hardwood and pine logs when maximum protection from all insect attack is desired. This formulation has consistently given a high degree of protection against ambrosia beetles and various wood borers for 3 to 4 months in numerous tests on hardwood logs and small bolts. In Nicaragua it was also found effective for about 4 months in preventing attack on slash pine by ambrosia beetles and various bark beetles during the rainy season.

Although this treatment will normally give adequate protection for about 4 months, under conditions of excessive rainfall and a high beetle population (as in the Tropics) spraying every 2 or 3 months may be necessary. This is true particularly on trees having smooth bark, since they do not absorb the solution readily.

Initial tests on red gum and white bay saw logs indicate that the use of carriers that are more viscous and less volatile than No. 2 fuel oil made the benzene hexachloride treatment last longer. When dissolved in a mixture of 1 part of SAE 70 motor oil to 19 parts of No. 2 fuel oil, or 1 part of tall oil (a by-product of the wood pulp industry) to 9 parts of No. 2 fuel oil, this insecticide was slightly more effective than when used in No. 2 fuel oil alone. These mixtures or similar ones may find use as vehicles for benzene hexachloride when long periods of pro-

[3] Benzene hexachloride is purchased in technical grades containing the gamma isomer in various concentrations. The percentage of gamma isomer in the material as purchased is stated on the package label or may be obtained from the manufacturer.

tection are desired or when extremely adverse logging and weather conditions are encountered.

Tests on small bolts indicate that the No. 2 fuel oil solution of benzene hexachloride remains effective after 6 weeks' submergence in running water. It appears, therefore, that treated logs may be floated to a mill site and remain free of attack for some time after they are removed from the water.

The oil solution should be applied when the bark is dry; wet bark does not absorb sufficient chemical to provide adequate protection. While water storage of logs is frequently and effectively employed to prevent attack by wood-boring insects, certain disadvantages are associated with the method. One of these is the fact that portions exposed out of the water become very severely infested. Treatment of these areas with the oil formulation will prevent insect attacks.

To prepare this oil solution dissolve in 50 gallons of No. 2 fuel oil, 17 pounds of technical benzene hexachloride when the gamma-isomer concentration is 10 percent, 12 pounds when it is 14 percent, and 4-2/3 pounds when it is 36 percent. Prepare the solution a day in advance of treatment and agitate it frequently to dissolve the chemical completely. Exposing the oil to the heat of the sun will speed up the dissolving process.

This solution can be prepared by the consumer for approximately 24 cents per gallon, 10 cents for the benzene hexachloride and 14 cents for the oil. The cost per thousand board feet varies with the size of the logs; it is about $1.00 to $1.25 for logs that average 14 to 16 inches in diameter, exclusive of the cost of application.

A concentration of benzene hexachloride sufficient to give 7/8 pound of the gamma isomer per 50 gallons of No. 2 fuel oil is recommended for the protection of pine saw logs and pine poles from attack by bark beetles and wood borers. It will not prevent attack of ambrosia beetles. This formulation has given protection to saw logs for about 4 months in tests conducted in the presence of a normal population of beetles. This solution can be prepared by using one-half the quantities of benzene hexachloride given above for each 50 gallons of fuel oil. It costs about 19 cents per gallon. The cost of the chemical alone per thousand board feet of lumber ranges from about $0.75 to $1.00 for logs 14 to 16 inches in diameter.

Tests with pine pulpwood for prevention of attack by bark beetles and wood borers have been conducted with most of the new insecticides. Benzene hexachloride at 7/8 pound of the gamma isomer per 50 gallons of No. 2 fuel oil has proved more effective than any other formulation tested. In the presence of a normal population of beetles this formulation has protected pulpwood for about 4 months. However, it was not entirely satisfactory in tests conducted on a pine-pulpwood storage yard in the presence of an overwhelming population of beetles. It therefore appears that this treatment should be satisfactory for use on these storage yards if started early in the spring before the beetles build up there. The treatment of all wood at the time it is placed in storage, beginning early in the spring and continuing throughout the season of beetle activity, should keep populations at a low level. The cost of the chemical for treating a cord of pulpwood is approximately $1.00.

Two percent of pentachlorophenol may be added to these solutions if control of sap stain is desired.

Concentrated solutions of benzene hexachloride which can be diluted with No. 2 fuel oil are on the market and are very desirable under certain conditions. However, their use increases the cost of treatment somewhat.

Concentrated oil solutions of benzene hexachloride applied with a mist blower have given erratic results on hardwood logs. When applied with a fog machine the concentrated solution was ineffective.

Wettable-powder suspensions. A suspension prepared from sufficient wettable benzene hexachloride to give 2 pounds of the gamma isomer per 50 gallons of water (20 pounds of a 10 percent gamma wettable powder) has given very good protection to hardwood logs against ambrosia beetles and wood borers for 3 to 4 months in limited tests. However, it has not been tested so fully as has the oil solution. It could be advantageous to use wettable powder where water is readily available and transportation of oil is a problem. At 15 cents per gallon for the spray the approximate cost of the chemical per thousand board feet is about 85 cents for logs 14 to 16 inches in diameter.

For the protection of pine logs and pulpwood against bark beetles and sawyers, benzene hexachloride at a concentration of 1 pound of the gamma isomer per 50 gallons of water (10 pounds of 10 percent gamma wettable powder) has shown promising results. In the presence of a normal population of beetles this formulation has given good results against Ips and sawyers, but has not prevented attack by

ambrosia beetles. Further investigations are needed, therefore, before it can be recommended generally. This formulation should cost about 45 cents per thousand board feet for logs 14 to 16 inches in diameter. The cost of the chemical for spraying pulpwood should be approximately 45 cents per cord.

Wettable benzene hexachloride can be used in combination with any of the common water-soluble sap-stain preventives.

Emulsions. Emulsions containing 1-3/4 pounds of the gamma isomer of benzene hexachloride per 50 gallons of water, prepared from numerous types of concentrates, have been tested with erratic results. Emulsions are inferior to the oil solutions and wettable-powder suspensions, but they afford some protection to logs for short periods.

Dusts. A benzene hexachloride dust containing 10 percent of the gamma isomer has given some protection to logs when applied at the rate of 5 pounds per thousand square feet of bark surface. It may find use where only short periods of protection are needed or when other formulations are not readily available. Heavy applications of this dust have prevented attack by black turpentine beetles on pine stumps for several weeks, and have aided in keeping these beetles under control in pine forests. In preliminary tests heavy applications of the dust have also shown promising results in protecting pine pulpwood from insect attack. A dosage of 2-1/2 pounds of dust containing 10 percent of gamma per thousand square feet gave inadequate protection to pine logs and pulpwood.

Other formulations. A 5 percent solution of heptachlor in No. 2 fuel oil has given promising results in a preliminary test for prevention of attack by ambrosia beetles on 2-foot sections of red gum saplings. Further tests are necessary, however, before its use can be recommended.

Lindane at 1-3/4 pounds, and benzene hexachloride at 1-3/4 pounds of the gamma isomer each in 50 gallons of No. 2 fuel oil, have been equally effective in preventing attack by ambrosia beetles on red gum bolts. However, the present high cost of lindane makes its use prohibitive.

The following formulations were ineffective against ambrosia beetles in preliminary tests: Undiluted coal-tar creosote; 5-percent TDE, 1-percent aldrin, and 1-percent dieldrin, each in No. 2 fuel oil; 1 part of 25 percent CS-645A to 500 parts of No. 2 fuel oil; No. 2 fuel oil alone; and 10-percent copper ammonium fluoride complex in water.

Treating Procedures

Time and rate of application. Spraying should be done as soon as possible after the trees are cut, within 24 hours in the Tropics.

The degree of protection obtained depends largely upon the thoroughness of application. Oil solutions, wettable powders, and emulsions of benzene hexachloride must be applied until all the bark of every log is dripping wet. Thorough wetting requires at least 1 gallon per 100 square feet of bark or the equivalent of 1 gallon for a log 24 inches in diameter and 16 feet long. About 6 gallons are required to treat a cord of pulpwood.

Stacking. Logs should be decked in long continuous rows to a height that can be readily sprayed to obtain maximum protection. Logs placed in the sun are less subject to damage by ambrosia beetles and sap stain than are those stored in moist shady locations. However, the duration of effectiveness of benzene hexachloride is reduced by direct exposure to sun and rain; hence log decks should be as high as it is practical to spray and the decks should be as long as it is possible to make them, so that fewer top and outside logs are exposed and more logs are inside the decks, where they receive the full benefit of the chemical.

Equipment. An ordinary hydraulic sprayer operated at a pressure of 200 pounds per square inch has proved satisfactory for spraying logs after they are stacked on the storage yard. It should be equipped with 50 to 100 feet of oil-resistant hose and an adjustable spray gun. The spray gun should be able to deliver a wide, cone-shaped spray for covering the tops, sides, and easily accessible portions of the log decks, and a narrow, stream-like spray for reaching the interior of the decks when directed into the spaces between the ends of the logs from each end of the deck. A No. 5 disc in the gun provides a satisfactory delivery rate for spraying at the pressure given. With this type of equipment one man can treat 6 to 8 thousand board feet per hour of continuous spraying.

Small garden or knapsack sprayers are satisfactory for use on individual logs before they are stacked, but not on stacked logs.

Where suspensions or emulsions of benzene hexachloride are used, the spray tank must be equipped with an agitator to prevent the chemical from settling.

Control Treatments. Occasionally the control of ambrosia beetles already in logs or lumber may be desirable. This is particularly true with imported logs when broods may emerge in the holds

of ships and build up a large populations of beetles, and in the shipment of green lumber where damage and reattack may continue for several days. It is sometimes necessary to kill broods of the southern pine beetle in logs and pulpwood to prevent spread of infestations.

Consequently tests have been conducted with dips and sprays of the new insecticides. Fumigation has also been tested, because this method of control may be adaptable for treating logs, lumber, or pulpwood particularly in the holds of ships or in boxcars.

Oil solutions. In preliminary tests sufficient benzene hexachloride to give 1-3/4 pounds of the gamma isomer in 50 gallons of No. 2 fuel oil applied as a 5-minute dip killed infestations in logs 12 inches in diameter. Further studies are necessary, however, before this method of control can be recommended. Spray applications of this formulation are ineffective against broods of ambrosia beetles in logs.

Investigations have shown that benzene hexachloride at 7/8 pound of the gamma isomer per 50 gallons of No. 2 fuel oil, applied by spraying at the rate of 1 gallon per 100 square feet of bark, will kill all stages of pine bark beetles and the immature stages of sawyers. This treatment is now being used successfully to control infestations of pine bark beetles in the South.

Fumigation. Preliminary tests indicate that logs can be fumigated with methyl bromide to kill broods of ambrosia beetles and bark beetles. A tight chamber equipped with some means of circulating the gas is necessary to obtain good results. Further investigations are needed before fumigation can be generally recommended. If this method of control can be perfected, however, it may find practical use in the treatment of infested wood that is shipped into areas where outbreaks are not occurring.

PROTECTION OF LUMBER

Preventive Treatments

Emulsions. A benzene hexachloride emulsion containing 5 ounces of the gamma isomer per 50 gallons of water applied by dipping is recommended to prevent attack of ambrosia beetles on lumber. This treatment has given good results under severe test conditions and in mill operations. However, during long rainy periods favorable for beetle activity it may be necessary to increase the gamma content slightly. The treatment can be applied readily in conjunction with measures of sap-stain prevention in which lumber is dipped in vats containing fungicides. The emulsion is compatible with the commonly used sap-stain preventives.

To make an emulsion having the proper amount of the gamma isomer for treating lumber, first prepare a concentrated solution by dissolving benzene hexachloride that contains 36 percent of gamma at the rate of 3-1/2 pounds per gallon of benzene, xylene, or other satisfactory solvent. Agitate, preferably with a motor-driven mixer, to dissolve the chemical. This gives approximately 5 quarts of solution for each gallon of solvent used. To each gallon of this concentrated solution add 1/2 gallon of No. 2 fuel oil, 4 ounces of Triton X-100, and 6 ounces of Triton B-1956. This combination makes an emulsifiable stock solution. To make the proper emulsion for dipping lumber add 1 gallon of the emulsifiable stock solution to 94 gallons of water. This emulsion costs about 2.1 cents per gallon. Approximately 15 gallons are required per thousand board feet of 1-inch lumber, at a cost of about 32 cents for the chemicals alone.

Emulsifiable concentrates of benzene hexachloride that can be diluted with water are on the market, but their use increases the cost of treatment.

Concentrated solutions and dust. Benzene hexachloride at a concentration of 1 pound of the gamma isomer per gallon of solvent applied with a mist blower at the rate of 3/4 pint, and dust containing 10 percent of gamma applied at the rate of 3/4 pound per thousand board feet have given good results under test conditions. These treatments can be applied to lumber after it is stacked; hence they allow for selective treating of only high-quality material. Unfortunately, it is easy to apply over-dosages, which result in excessive costs, particularly in the mist treatment. When applied at the rates given above, each formulation costs about 25 cents per thousand board feet. Concentrated benzene hexachloride solutions applied with a fog generating machine were ineffective.

Control Treatments

Oil solutions. The control of ambrosia beetles in lumber may be desirable under certain circumstances, such as the shipment of green infested lumber. In preliminary tests on logs a 5-minute dip in an oil solution containing sufficient benzene hexachloride to give 1-3/4 pounds of the gamma isomer per 50 gallons was effective. A dipping period of considerably less than 5 minutes may be ample for killing the insects in lumber, but this point has not been investigated. However, lumber treated by this method may retain enough benzene hexachloride after planing to make it unsafe for certain usage, such as crates

or casks for storage of products for human consumption. This point is being investigated.

Emulsions. A benzene hexachloride emulsion containing 1-3/4 pounds of the gamma isomer per 50 gallons applied as a 5-minute dip was ineffective in killing broods of ambrosia beetles in 1-inch lumber. Emulsions were also less effective in killing broods of bark beetles in pine than were oil solutions.

Fumigation. Preliminary tests with methyl bromide indicate that ambrosia beetles in green lumber and bark beetles in pine pulpwood can be killed by fumigation. Further investigations are needed to determine proper dosages and exposure periods. Control of powder-post beetles in seasoned lumber and tool handles has been obtained with dosages of 1, 3, and 9 pounds of methyl bromide per 1,000 cubic feet at exposure periods of 24, 16, and 3 hours, respectively.

GENERAL PRECAUTIONS IN HANDLING INSECTICIDES

Oil solution of benzene hexachloride can be absorbed through the skin. Clothing accidentally wet with the material should be removed as soon as possible. Any of the chemical spilled on the skin should be washed with warm soapy water.

Mists, dusts, and wettable powders of benzene hexachloride are irritating to the skin, eyes, and nostrils, and may cause further trouble if inhaled in quantities. Persons applying mists and dusts should wear respirators and goggles.

Benzene and xylene are flammable and precautions should be taken in handling them.

Continued exposure of the skin to methyl bromide may result in burning. A gas mask should be used in applying it to avoid inhaling the gas.

REFERENCES

Anonymous. 1951. The Black Turpentine Beetles Can Kill Trees. Jour. Amer. Turpentine Farmers Assoc. 13(9):7,14.

Johnston, H. R., and R. J. Kowal, 1949. New Insecticides for the Prevention of Attack by Ambrosia Beetles on Logs and Lumber. South. Lumberman 179(2249):183-188.

Kowal, R. J. 1949. Control of Wood-Boring Insects in Green Logs and Lumber. Forest Prod. Res. Soc. Proc. 3:469-479.

Kowal, R. J. 1949. Benzene Hexachloride for the Control of Insects Attacking Green Logs and Lumber. Down to Earth 5(2):12-13.

Kowal, R. J. 1950. Insects Commonly Attacking Forest Trees and Unseasoned Timber in the Southern States. Forest Farmer 9(5):28-31.

Verrall, A. F. 1941. Dissemination of Fungi That Stain Logs and Lumber. Jour. Agr. Res. 63:549-558.

Verrall, A. F. 1943. Fungi Associated with Certain Ambrosia Beetles. Jour. Agr. Res. 66:135-144.

Treatability of Southern Yellow Pine as Influenced by Fungus Infection[1]

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Two articles relating to studies on the preservative treatment of southern yellow pine fence posts appear in the June 1952 issue of the Journal of the Forest Products Research Society. The authors report on different approaches to the important problem of meeting the increased farm demand for well-treated fence posts. In each case, however, it is not clear that the investigators have considered the highly significant influence of fungus infection on the results of treatment. It is now known that the so-called harmless molds greatly influence the permeability of southern yellow pine.[2, 3] Indications in both studies, such as the high preservative retentions referred to and, in one case, the close piling of posts in cribs during seasoning, strongly point to the possible infection of the posts used in the studies. Fungus infection, furthermore, is quite common in southern yellow pine posts and is not always readily apparent. Surface molds do not generally discolor the interior of the wood and may be washed from the surface of poles or posts during a heavy rain.

West, in one of the above-mentioned Journal articles, "A Modified Method for the Preservative Treatment of Southern Pine Fence Posts" (pp. 85-88), in discussing the cold-soaking process, for example, states: "With southern pine, the time required to obtain proper retention varies from 15 hours down to 15 minutes."

Exception is also taken to the other Journal article by Schnell on "Treatability of Shortleaf Pine by the Cold Soaking Method" (pp. 80-84), particularly to the conclusion reading as follows:

> "1. Treating time varies inversely with post diameter. Four-inch posts treat in half the time required for three-inch posts. Five-inch posts require 13 percent less time than the four-inch ones."

These statements are correct, and the results are typical as they apply to fungus-infected southern yellow pine posts. They are incorrect for uninfected posts in the light of experience in several studies, beginning late in 1941, at the Forest Products Laboratory in cold-soaking posts of these woods.

RETENTION VARIES WITH INFECTION

Variations in the average preservative retentions obtained at the Forest Products Laboratory in the cold soaking of full-length fence posts of fungus-infected and uninfected southern yellow pine are indicated by the curves in Figure 1. Curve A in this figure shows the high retentions possible during short soaking periods in longleaf pine posts. These posts were cut during July 1948 and seasoned under adverse conditions at MacNeill, Miss. The posts showed blue stain, mold growth, and some incipient decay. Curve B of Figure 1 shows the somewhat lower retentions obtained in soaking longleaf pine posts that were cut at the same time and place but dipped in a stain-control chemical soon after cutting. These posts were shipped to the Forest Products Laboratory at Madison, Wis., where they were air seasoned for 2 months under somewhat more favorable temperature and moisture conditions than those prevailing at the time in Mississippi. The posts represented by curve B were in much better condition, but some evidence of fungus infection was noted. Curves C and D of Figure 1 show the retentions of preservative obtained in southern yellow pine posts that appeared to be entirely free from fungus infection. One of these two groups of posts was cut during May 1942 at Willow Springs, Mo., and air seasoned approximately 2 months before shipment to Madison, Wis., for treatment, while the other group was cut at Crossett, Ark., during the month of April 1942 and air seasoned approximately 3 months before shipment to Madison. It may be noted that preservative retentions obtained in the uninfected posts, even after

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[1] A contributed paper to the Journal of the Forest Products Research Society.

[2] Maintained at Madison, Wisconsin, in cooperation with the University of Wisconsin.

[3] Lindgren, Ralph M. Permeability of Southern Pine as Affected by Mold and Other Fungus Infection. Paper presented at the April 1952 meeting of the American Wood-Preservers' Association in New York City.

[4] Lindgren, Ralph M. and Harvey, George M. Decay Control and Increased Permeability in Southern Pine Sprayed with Fluoride Solutions. Paper presented at the June 1952 meeting of the Forest Products Research Society, Milwaukee, Wis.

soaking periods of from 2 to 7 days, were considerably below those reported by West and Schnell, while those obtained for the badly and slightly infected posts corresponded more closely to the retentions referred to by these authors.

INFLUENCE OF POST DIAMETER

The above-mentioned southern yellow pine posts from Crossett, Ark., were divided, prior to treatment, into three diameter classes, and the average preservative retentions obtained in five post groups during different soaking periods are shown in Table 1. It may be noted from the data on uninfected southern yellow pine, given in the table, that the posts of larger diameters show somewhat lower retentions but deeper penetration of the preservative than those of smaller diameters. The difference, however, is not great. These results are opposite to those reported by Schnell.

Attention has been recently called by Lindgren and Harvey[3, 4] to the importance of mold and other fungus infection as influencing the permeability of various southern yellow pines. The work of these investigators helps to explain and confirm the high preservative retentions frequently noted in the cold-soaking and hot-and-cold bath treatments of posts and poles of those species. While fungus infection is often difficult to control, it is possible, through cutting and seasoning the posts under optimum weather conditions, to reduce its effects on preservative treatment. Whether or not the high retentions are desired, it is highly important that this factor not be overlooked in studies on the treatment of posts, since it is the most significant of the variables influencing preservative retentions in round pine in nonpressure processes.

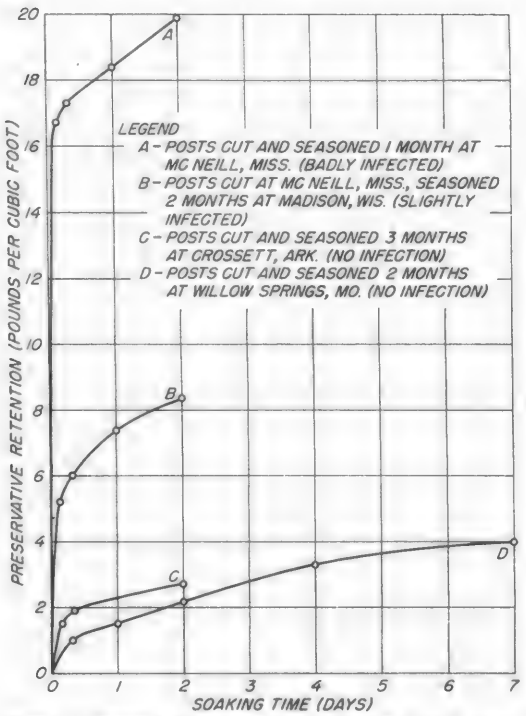

Figure 1.-- Retentions of low-viscosity preservative oils in fungus-infected and uninfected southern yellow pine posts treated by the cold-soaking method.

Table 1.--Retentions and penetrations of low-viscosity preservative oils obtained in the cold-soaking treatment of full-length air-seasoned southern yellow pine posts of different diameters

Average top diameter	Average preservative retention	Average sapwood depth	Average penetration depth
Inches	Lb. per cubic foot	Inches	Inches
	Soaking Time - 4 Hours		
3.2	1.5	1.57	0.29
4.1	1.5	1.74	.46
5.0	1.4	1.71	.47
	Soaking Time - 8 Hours		
3.3	2.0	1.64	.63
3.9	1.9	1.46	.71
5.2	1.7	1.84	.95
	Soaking Time - 24 Hours		
3.3	2.1	1.20	.52
4.1	1.9	1.71	.84
5.5	1.7	2.00	.89
	Soaking Time - 48 Hours		
3.2	3.0	1.35	1.15
3.8	2.7	1.47	1.32
5.3	2.5	1.67	1.40

Panel Discussion on Glues and Gluing

1. Animal Glues in Woodworking[1]

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DESCRIPTIVE

Animal glue adhesives are essentially organic colloids of complex protein structure extracted by a simple steeping in warm water from properly prepared collagen-bearing animal materials common to the meat packing and tanning industries. Their use in wood joinery dates back to antiquity.

Hofmeister (3)[2] describes gelatine (glue) as hydrolized collagen and gives the following formula:

$$C_{102}H_{149}O_{38}N_{31} + H_2O = C_{102}H_{151}O_{39}N_{31}$$
(collagen) (gelatine)

The two principal types are:

(1) Hide glues, derived from the collagenous materials present in trimmings and connective tissues associated with the hides principally from cattle.

(2) Bone glues, both naphtha extracted and "green"types, are derived from the collagen present in bones.

Contrary to some commonly accepted misconceptions, animal glues cannot be derived from horns and hoofs, nor the carcasses of dead animals.

As a group, the hide glues are the strongest and most versatile of the animal glues as to broad usage in woodworking. Certain operations requiring but moderate adhesive strength find ample bonding power with the bone glues, particularly the naphtha-extracted type in the medium jelly strength range.

As commercially marketed in granular form, animal glues are hard, dry, hornlike, odorless materials somewhat transparent, ranging in color from light amber to dark brown. They can be supplied, if desired, in flake, pearl or pulverized forms. Their moisture content ranges from 11 to 14 percent (loss in weight), 12 percent being a fair average. An ash content of 3 to 4-1/2 percent is normal. The hide glues are practically neutral in reaction, pH range 6.4 to 7.4; bone glues may be slightly acidic, pH about 6.0. The specific gravity is considered to be 1.27.

Animal glues are also marketed commercially to a limited extent as prepared liquid adhesives of high solids concentration. Such preparations which have excellent flow properties at normal room temperatures are well suited for many assembly operations in woodworking, particularly the newer type compression dowels and tenons. Their slow-setting properties allow sufficient moisture transfer to expand the compressed wood to a tight fit before drying.

All animal glues possess physical and chemical properties unique among adhesives:

(1) Placed in cold water, they do not readily dissolve but absorb considerable water, swelling to a spongy mass of jelly-like particles. Upon heating gently this jelly-like sponge readily melts into solution in a temperature range of 105° F. to 140° F. No auxiliary chemicals are required for dissolving.

(2) While it is physically possible to dissolve finely pulverized glues directly in hot water, such practice is not recommended for woodworking glues.

(3) Glue solutions upon cooling set to a firm jelly. As reversible colloids they readily revert to a solution upon application of heat. This rapid development of the jellied state upon spreading provides fast "set", "tackiness", and initial holding strength.

(4) Dried films deposited from warm solutions are non-crystallizing and continuous, of great strength and elasticity. The tensile strength is calculated to be in excess of 10,000 pounds per square inch, or far in excess of normal industrial demands.

(5) These dried films may be made moisture resistant by suitable practical methods when such properties are desired.

(6) Cold, liquid, animal glue solutions for application at normal room temperatures are

[1] Presented at meeting of Forest Products Research Society, Northeast Section, York, Pennsylvania, May 22 and 23, 1952.

[2] Numbers in parentheses refer to literature cited at the end of this paper.

prepared by the controlled addition of jell-depressant salts to hot glue solutions, precluding their regelation upon cooling to temperatures in the range of 65° to 80° F.

(7) The rate of "setting" of spread glue films can be retarded by properly controlled additions of limited amounts of these same jell-depressant salts.

(8) The improved "wetting" and penetration of certain difficult surfaces, for example oily-like cedar, can be obtained by adjusting the surface-tension properties of glue solutions by the controlled addition of sulphonated oils.

(9) To preclude foaminess upon agitation in mechanical spreaders, producers supply glues properly "defoamed" by controlled addition of fat emulsions.

(10) Dry animal glues may be stored indefinitely with no loss in strength, solubility, or other chemical or physical properties, provided they are not subjected to soaking or wetting with water from leaking pipes, roofs, or other sources. Extremes of temperatures and humidity in normal dry warehousing have no adverse effects.

GRADING

Animal glues are evaluated for pricing on the basis of comparative jelly strength values and viscosity characteristics following simple measurement procedures adopted by the National Association of Glue Manufacturers. The descriptive terms for these measurements, taken at fixed concentrations and temperatures, are:

(a) Jelly strength in "grams"; the weight required to depress a given sized plunger a fixed depth into a glue jelly using the Bloom Gelometer.

(b) Viscosity (flow properties) in "millipoises"; the resistance to flow of a standard glue solution through an orifice of known constants at a given temperature.

Broadly speaking, jelly strength values range from about 30 grams (very weak jelly) to 500 grams (exceptionally strong jelly). Viscosities range from 25 millipoises (quite watery) to about 200 millipoises (extremely heavy bodied).

Intermediate grades are spaced at intervals approximating 30 grams.

Complete technical data on these grading procedures are given by De Beauklaer, Powell, and Bahlmann (1, 2)

GLUE GRADES FOR WOODWORKING

For general assembly and edge gluing there are three major groups of animal glues - all providing a wide margin of safety and a shearing strength in excess of that of the wood itself, differing only in inherent strength, elasticity, and shock resistance properties.

(1) For maximum strength and shock resistance.
Jelly strength grades in range 300 to 400 grams.

(2) For average strength and shock resistance.
Jelly strength grades in range 200 to 300 grams.

(3) For non-critical strength and shock resistance
Jelly strength grades in range 135 to 200 grams.

With a given jelly strength value and for soft porous woods, a fairly heavy bodied glue is employed; for close grained woods a moderately thin bodied glue is desirable. This variation in the glue concentration of a given test grade of glue, depending on the type of wood, leads to consistent gluing results through control of such factors as the optimum thickness of spread, degree of penetration and anchorage into both faces of the wood, the holding of the film at the joint (glue line) and control of "set" and duration of "tack: at the joint face.

The jelly strength values usually selected by the woodworking industries range from a medium strength grade approximating 165 grams test (the Peter Cooper Standard grade No. 1-3/8,) upwards to approximately 380 grams test (the Peter Cooper Standard grade No. A Extra).

In plants where stock used is almost entirely the softer porous woods, principally conifers, the average preference is for a glue testing 190 to 200 grams, like the Peter Cooper Standard grade No. 1-1/4. Where the stock is more diversified, with the trend toward denser close-grained woods such as maple, birch, and some oaks, the preference is for higher testing glues, centering around 250 grams, such as the Peter Cooper Standard grade No. 1XM. The use of higher jelly strength values in woodworking is generally limited to plants using close grained hardwoods exclusively where maximum shock

resistance is desired; glues testing in range 315 to 380 grams, such as the Peter Cooper Standard grades No. 1 Extra Special to No. A Extra being selected.

The following table indicates the average approximate ratio of water to glue by weight employed in preparing this broad range of animal glues for woodworking applications where wood and room temperatures are in the range 74° to 80° F., and glue temperature 140° F.

	Grades	Water-to-glue ratio	
Gram	Peter Cooper	Porous	Close-grained
Test	Standards	Woods	Woods
380	A Extra	3:1	3-1/4:1
350	1 Extra	2-3/4:1	3:1
315	1 Ex. Spl.	2-1/2:1	2-3/4:1
285	1	2-1/4:1	2-1/2:1
250	1XM	2-1/4:1	2-1/2:1
220	1X	2:1	2-1/4:1
195	1-1/4	1-3/4:1	2:1
165	1-3/8	1-1/2:1	1-3/4:1
135	1-1/2	1-1/4:1	1-1/2:1

GLUE PREPARATION

The preparation of animal glue solutions for woodworking is quite simple. Jacketed cookers or melters, for indirect application of heat, preferably thermostatically controlled, are employed. The correct amount of cold water is poured in first, the specified weight of dry glue is then slowly added with good agitation to the cold water and thoroughly mixed. The batch is allowed to soak and swell for about 1 to 2 hours to completely soften all particles, then is melted by turning on the heat, bringing the temperature up to 140° to 145° F. It is then ready for application at that temperature range.

While animal glues will stand considerable abuse in their preparation and application, there are several basic considerations to be observed to insure users consistently uniform working properties and maximum economies. For best results, always:

(1) Use clean equipment
Clean equipment means clean glue solutions. Good housekeeping pays off just as much in the glue room as elsewhere in the factory. All cookers, mixers, pails, pots, spreaders, brushes, etc., should be thoroughly scalded and cleaned daily.

(2) Weigh glue and water
Correct water-to-glue ratios insure uniform, consistent working properties of the glue solution. Water may be measured, but must be calculated in terms of weight. Always put the dry glue on a scale to check its net weight. Don't guess.

(3) Soak in clean cold water
Only clean, cold tap water, safe for drinking purposes should be used. Boiler condensate waters should be avoided due to risk of chemical contamination.

(4) Pour dry glue into water
To avoid lumping or balling of glue particles, always sift the dry glue into the clean, cold water slowly, with rapid agitation, stirring until well dispersed and all particles are wetted. Allow it to soak 1 to 2 hours to permit complete softening and swelling before melting.

(5) Prepare fresh batches frequently
It is false economy to attempt to fortify previous batches by adding dry glue to them. Its solubility is very slow, and the concentration becomes immediately unbalanced. In many plants the procedure is to prepare only sufficient quantity for one 8-hour shift at a time, others even limit batches to 4-hour intervals. The heat should be turned off left-over batches at day's end, keeping cool overnight, re-melting and using them up the first thing next morning.

(6) Use gentle heat
Properly soaked, swollen glue melts readily at temperatures from 105° F. to 140° F. Localized overheating around sides and bottom of melter is eliminated and the rate of melting accelerated by moderate agitation at 20 to 30 rpm. Temperatures for melting, storage, and application above the range 140° to 150° F. are unnecessary, wasteful of heat, increase evaporation losses, retard rate of "set" and introduce needless variables. The direct use of steam from open jets in contact with glue must be avoided. Drastic localized overheating and the added condensate materially affects the quality of the final solution.

Most large consumers maintain a central glue preparation department with a well trained operator in charge who is held responsible for the cleanliness of the department and its equipment, as well as the uniform preparation of all batches and their distribution. Such a department is usually laid out along these lines:

(1) An elevated platform is erected with one or more glue-melters mounted thereon. Ample space for dry glue storage, a scale for weighing, and a convenient cold water line are provided.

(2) On floor level is a jacketed storage tank to which melted glue flows by gravity, being drawn off as required for distribution to individual bench pots, spreaders and other gluing equipment.

(3) A large deep sink equipped with running hot and cold water, and ample drainboard space (galvanized or other rustproof metal) provided for cleaning equipment.

(4) A supply of clean galvanized pails is always available exclusively for glue weighing and water measurement.

The several manufacturers of equipment for the preparation, storage and application of animal glues publish descriptive catalogues of such equipment and can offer suggestions as to glue-room layout for most advantageous results.

POT LIFE

When held at the recommended temperature range of 140° to 145° F., animal glue solutions, due to their large safety factor in strength, enjoy long pot life without severe breakdown. The gradual degradation at these temperatures is relatively insignificant over an 8-hour period. Carelessness, permitting continued over-heating at temperatures elevated much above 140° F. will, however, cause somewhat rapid deterioration. For example, a batch held for 8 hours at approximately 180° F. can lose at least 50 percent of its strength (shock resistance).

COVERAGE

The spread of animal glue solutions per unit area of wood surface is a variable depending upon the type of wood, test grade value of glue employed, and manipulation factors. Spreads of from 40 to 60 square feet per pound of dry glue are normally obtained; and are approximately in ratio to the test grade value of glue.

In June 1929, the United States Department of Agriculture published Department Bulletin No. 1500, entitled "The Gluing of Wood" by T. R. Truax (7), of the Forest Products Laboratory. This publication has been an invaluable guide ever since to both the woodworking and adhesive industries. An interesting table, No. 7 on page 51, presents a gluing schedule in three series at specific water-to-glue ratios showing the coverage at three different temperatures of wood (70° to 90° F.), under various pressures and times of assembly. A condensation from this table is given on page 91 . The grade of glue employed tested approximately 315 grams jelly strength, equivalent to the Peter Cooper Standard grade No. 1 Extra Spl. The data disclose that such a grade at 2-1/4 parts water to 1 part glue by weight, with a wood temperature of 70° F. has a coverage approximating 47 square feet per pound of dry glue, which may be slightly increased with warmer wood temperatures approaching 90° F.

Of particular interest to the West Coast wood utilization industries is the work of W. Z. Olson, at the Forest Products Laboratory, covering a series of tests on gluing characteristics of four West Coast hardwoods: chinquapin, tanoak, California laurel, and madrone. In keeping with the earlier work described in Bulletin No. 1500 a 315 gram jelly test value glue, equivalent Peter Cooper Standard No. 1 Extra Spl., was likewise employed, using this grade at 2-1/4 parts water to 1 part glue by weight at 140° F., with wood temperature at 80° F., a wood moisture content of 8 percent an average spread of 44 grams per square foot (one side application only), 3 minutes closed assembly and 200 lbs. per square inch pressure, shear test results were secured as follows:

Species	Shear strength psi.	Wood failure percent
California laurel	2,929	50
Chinquapin	1,749	92
Tanoak	3,042	74
Madrone	2,675	84

DISCUSSION OF APPLICATION PRINCIPLES

The acceptance of animal glues in the woodworking and furniture industries beyond the memory of living man reflects such inherent qualities as permanence of bonding, versatility and ease of application, stability under world wide atmospheric conditions, and economy of use.

Marra (4) has indicated that the formation of a bond is dependent upon 3 groups of factors:

(1) Composition of the glue.
(2) Handling of the glue.
(3) Condition of the stock.

Woods	Water-to-glue ratio by weight	Glue solution spread[1]	Wood temp. °F.	Pressures lbs. per sq. inch	Closed assembly time
Series 1					
Cedar (western red), chestnut, Cypress (southern, sapwood), Douglas-fir, white fir, hemlock (western), pine (northern white), redwood, spruce	2-1/4:1	60-65	70	100-150	0-1 min.
	2-1/4:1	65-70	80	" "	1-5 "
	2-1/4:1	70-75	90	" "	3-20 "
	3:1	70-75	90	" "	5-20 "
Series 2					
Alder (red), butternut, cedar (Alaska), cedar (eastern red, sapwood), cottonwood, mahogany, pecan, pine (southern and western yellow), sassafras	2-1/4:1	65-70	70	125-175	1/3-1 min.
	2-1/4:1	70-75	80	" "	2-5 "
	2-1/4:1	75-80	90	" "	7-18 "
	2-3/4:1	75-80	90	" "	10-20 "
Series 3					
Ash, basswood, beech, birch cedar (eastern red, heartwood), cherry (black), cypress (southern, heartwood), elm (American and rock), gum (black, red and tupelo), hickory, magnolia, maple, oak (red and white), osage orange, persimmon, sycamore, walnut (black).	2-1/4:1	65-70	70	150-200	1/2-1 min.
	2-1/4:1	70-75	80	" "	3-5 "
	2-1/4:1	75-80	90	" "	10-18 "
	2-1/2:1	75-80	90	" "	12-18 "

[1]Lbs. liquid weight per 1,000 sq. ft.

He describes the five links of a joint as:

(1) The wood and its surface on one side.
(2) The bond between the glue and wood on one side.
(3) The glue film.
(4) The bond between the glue and wood on the other side.
(5) The wood and its surface on the other side.

He further states a glue must perform five distinct, but interdependent movements to form a bond:

(1) Flow laterally into a film.
(2) Transfer to the adjoining surface.
(3) Penetrate into both surfaces, spread and unspread.
(4) Wet the wood substance.
(5) Solidify.

The soundness of the bond is dependent on the extent to which each movement has progressed, keeping in mind that these movements occur in sequence beginning with flow and ending with solidification. Solidification arrests the sequence at any point creating characteristic patterns on the glue line which may be identified with the predominant factors in the gluing operation.

In production line edge gluing for table tops, panels, chair bottoms or similar large area surfaces; the preparation of corestock for subsequent veneering; and the building up or laminating face to face of members to provide blanks for subsequent turning of heavy legs, posts and decorative parts, speed of operation is an economic factor.

It is characteristic of warm animal glue solutions to:

(1) Readily flow or spread to a film.
(2) Transfer easily to the opposite face of the member to be joined.
(3) Penetrate and wet both surfaces without undue "bleeding-in" or migration (hold at glue line).
(4) Set rapidly, developing immediate tackiness and initial joint strength, yet have sufficient latitude in speed of set and corresponding duration of tack to fit

such specific slower assemblies requiring appreciable length of time before pressure can be applied.

(5) While primarily a film former, not a filler, its flexibility is reasonably tolerant of slight imperfections and gaps in machined matching surfaces to be glued.

The rate of set and duration of tack of any warm animal glue solution depend upon several factors, among which are:

(1) The viscosity of the solution and its concentration (water-to-glue ratio.)
(2) The jelly strength value of the glue used.
(3) The temperature of the glue solution.
(4) The temperature of the wood at time of application.
(5) The room temperature of the assembly area and its relative humidity.
(6) The presence or absence of drafts of cold air (open or broken windows, open doors).
(7) The depth of glue film deposited at face of joint.
(8) The employment of jell-depressant salts.

The greater the viscosity of the solution (and its concentration), the higher the jelly strength value of the glue employed, the cooler the temperature of the wood and the assembly area, and the dryer the surrounding atmosphere, the more rapid the setting rate. Conversely the lower the viscosity, the lower the jelly strength value of the glue (and its concentration), the warmer the wood and the assembly area, and the damper the surrounding atmosphere, the slower the setting rate. By proper choice of the above variables a broad working range is provided covering all general woodworking operating conditions.

In recent years there has been increasingly greater interest displayed in the use of jell-depressant salts with animal glues. These salts are added directly to and dissolved in the warm glue solution, in amounts sufficient to obtain the working characteristics desired, relative to retarding the rate of jelling (or setting) and prolonging the tacky period of the film. They are also employed to modify the concentration to permit increased glue solids when desired and still retain control over setting time for certain specific wood conditions. If sufficient quantity is added, a cold liquid solution of good fluidity for application at normal room temperatures in the range of 65° to 85° F. is obtained. The preferred salts are those which only physically depress the rate of jelling or setting, with no adverse chemical effects upon the structure of the glue, producing joint strengths indistinquishable from those obtained using a normal unmodified warm glue solution. Thiourea is one salt that has preferred acceptance.

Cold liquid animal glue solutions are particularly well suited for assembly work employing the new type compression dowels, such as the Rahaim "ExpanDowel", and the Valiton compressed tenon. Their fluidity is excellent for application in Fox, Binks and similar air pressure operated glue guns, squirt cans of the oiler type, and hand syringes, as well as by brushing.

MOISTURE RESISTANT ANIMAL GLUE JOINTS

There are many instances where through trade demands a moisture resistant joint is desired. The actual need for moisture proof joints, particularly in the sense of so-called "water-proof" joints in furniture, cabinets and musical instruments, except for a few extremely humid sub-tropical areas has been more or less exaggerated and over-emphasized. Furniture and musical instrument assemblies employing untreated and unmodified animal glues have for many decades successfully withstood all usual climatic conditions the world over.

When desired, moisture resistant animal glue joints can be made by a simple, practical method.

The following procedure is suggested:

(1) The usual warm glue solution is prepared in normal manner.

(2) To one face only of the joint to be assembled, apply by brushing or sponging, a solution made up of one pound (1 pint) of commercial formaldehyde (40 percent Formalin) and 9 pounds (9 pints) of water in which has been predissolved 8 ounces (one-half pound) of borax. Allow the excess moisture to be absorbed from the surface of the wood.

(3) The warm glue solution is applied in the regular manner to the matching (opposite) face of the assembly.

(4) The formaldehyde-borax treated and the glue covered faces are then assembled and placed under pressure with usual clamping procedures.

(5) After drying, the glued assembly is removed from clamps and allowed to season for 5 to 7 days to permit full moisture

resistant properties to develop.

CONTROL OF JOINT FAILURES USING ANIMAL GLUE

In an earlier section on the subject of glue coverage, reference was made to Department of Agriculture Bulletin No. 1500 published in June 1929 as a valuable guide to gluing operations. No discussion pertaining to occasional failures in gluing with any adhesive would be complete without reference to the "Manual of Gluing" prepared at the Engineering Research Institute, University of Michigan, by Alan A. Marra (4) in cooperation with the School of Forestry and Conservation and published by the National Association of Furniture Manufacturers. It is an excellent companion guide to the Department of Agriculture's Bulletin.

Marra (5) has said that a well bonded joint is the result of conditions which allow the adhesive to adequately penetrate and wet both surfaces, produce a continuous film between, and solidify to a hardened state in intimate association with all of its component ingredients and the wood substance.

In the gluing of wood with any type or kind of adhesive there are occasional joint failures. As the bonding power of the several grades of animal glues described are far in excess of the shearing strengths of the numerous woods commercially employed, the factors leading to joint failures should be carefully checked. Among such factors are:

(1) Improperly dried or conditioned wood.
The moisture content equilibrium should be that under which the finished product will be used, ranging from 6 to 10 percent, and the wood should be free from case hardening and stresses. Too high, too low or a non-uniform, poorly distributed moisture content will contribute to failure.

(2) Poorly dressed or machined stock.
Glue is not a filler, the joint faces should be true and tight fitting for optimum results.

(3) Temperature of wood upon application.
(a) Too warm, above 90° F., danger of excessive penetration. (starved joints).
(b) Too cold, below 70° F., danger of chilled, prematurely set glue film before assembly. (Poor penetration and transfer.)

(4) Temperature of glue solution
Normal temperature upon application should be 140° to 145° F.
(a) Excessively higher temperatures break down glue structure, reduce strength, and cause severe evaporation of water content, changing proper concentrations.
(b) Excessively lower temperatures thicken viscosity, contributing to too rapid setting, poor flowability and spread, failure to wet properly and penetrate both surfaces.

(5) Glue Spread
A thin, uniform, well distributed film at proper concentration and temperature should completely cover one face of the assembly and readily transfer to the opposite face upon assembly.
(a) Insufficient glue spread contributes to a starved joint.
(b) Excessive glue deposit, too much spread, is nearly as bad as too little. Too thick a deposit is wasteful, adds excess moisture to the wood, causes slippage from position while being pressed or clamped.

(6) Timing of assembly
Assembly should be made as soon as the glue film begins to set (becomes tacky to touch with finger).
(a) A premature assembly squeezes out too much glue, leaving an insufficient film as in 7 (b) below.
(b) Excessively delayed assembly permits glue film to harden, preventing proper transference of glue to opposite face.

(7) Clamping
Uniformly distributed pressures in range of 100 to 200 lbs. per square inch are recommended as reasonable.
(a) Insufficient pressures fail to bring individual members into alignment, fail to remove air and excess glue, and also fail to hold members rigidly in position during development of adhesive strength.
(b) Excessive pressures squeeze out too much glue solution leaving insufficient adhesive essential for good bonding.

(8) Premature removal from clamps.
Stock should remain under pressure until initial joint strength has developed; at least 30 minutes to 1 hour or longer as conditions indicate.

(9) Improper drying conditions after assembly.
There are known limits to the capacity of air to pick up and hold moisture, the higher its temperature the greater the capacity. Overburdened moist air in the area surrounding the clamping and drying equipment should be constantly removed by exhausting without excessive draft. A normal temperature of 70° to 85° F. with relative humidity approximating 50 percent is considered safe. Excessively high temperatures may remelt set glue, causing bleeding.

(10) Improper choice of glue or glue concentration for specific type of assembly and wood species.
(a) Too heavy concentrations penetrate inadequately.
(b) Too thin concentrations penetrate excessively, bleed-in and starve the joint, leaving inadequate glue film at glue line.

Animal glue is without any question one of the simplest and most trouble free adhesives available for industrial use following the ordinary common sense precepts of practical woodworking operations. The fact that animal glues have without interruption been employed in woodworking for more than 3,000 years without going out of style permits them to carry the title of "old fashioned" with well earned pride.

All technical data herein contained are offered solely for general informative purposes. For specific recommendations in the preparation and use of animal glues consult your glue supplier.

LITERATURE CITED

1. De Beauklaer, S. L., Powell, J. R., and Bahlmann, E. F. 1924. Standard Methods for Determining Viscosity and Jelly Strength of Glue. Ind. Eng. Chem. Vol. 16, No. 3. 310-315.

2. _____. 1930. Standard Methods (Revised) for Determining Viscosity and Jelly Strength of Glue. Ind. Eng. Chem. (Anal. Ed.) Vol. 2. No. 3. 348-351

3. Hofmeister, F., Z. physiol. Chem. 2:299 (1878). See also Bogue, R. H., "The Chemistry and Technology of Gelatine and and Glue", 1st edition page 49, New York, McGraw-Hill Book Co., 1922.

4. Marra, Alan A. 1950. Manual of Gluing. University of Michigan School of Forestry and Conservation in cooperation with National Association of Furniture Manufacturers.

5. _____. 1950. "The Behavior of Glue", paper presented at Gluing Short Course, No. Carolina State College of Agriculture, Raleigh, N. C., April 1950.

6. Olson, W. Z. 1949. Some Tests on the Gluing Characteristics of Four California Species--Chinquapin, Tanoak, California Laurel, and Madrone. Calif. Lbr. Merchant. June 48-52.

7. Truax, T. R. 1929. The Gluing of wood. U. S. Dept. Agr. Bull. 1500.

2. Casein Glues[1]

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HISTORY

Casein, the technical name for the protein of milk, has been in use as an adhesive for wood for many years, dating back to the Egyptian, Greek and Roman eras. It is made by curdling milk with acid and in appearance resembles "bakers cheese" or "cottage cheese" before processing. The first commercial production of casein in the United States was started in 1895 by The Casein Manufacturing Company (now a division of the Borden Company). However, the use of casein for glues did not become extensive until 1915, stimulated by World War I demands for water-resistant plywood for the fuselage of airplanes. The first use was in a so-called wet mix formula, consisting, for example, of ground casein, hydrated lime, silicate of soda, copper chloride and water (combined cold in the user's plant). This is still in limited use today. The development of "one part" glues during World War I proved to be a definite advancement providing uniform glues of heretofore unobtainable water resistance. During the years that followed, greater commercial development occurred through the modification and improvement of the somewhat crude war-time formulas, to meet the widely varying requirements of the wood-working industry.

GENERAL PROPERTIES

Before the introduction of synthetic resin adhesives, certain formulations of casein glues were classed as "water-proof", but this was a misnomer because, they are only "water-resistant" from the standpoint of complete durability to exterior conditions or continuous submersion in water. However, in general, a casein glue line while weakened by the presence of moisture will regain practically its original strength when again dried out.

Casein glues are chiefly composed of dried and ground casein, hydrated lime, other alkalies, and water. Generally, the percentage of lime determines the degree of water resistance and through the incorporation of minor quantities of other special ingredients, the wide variety of types are attained. The chemistry of "one-part" casein glues involves several steps which result in the final durable glue lines. The lime has the dual purpose of forming strong caustic alkali which dissolves the casein, then slowly reacts with the soluble casein to form the water-resistant end product. It might be well to mention that raw caseins vary considerably in quality, with certain types more suitable for glues than others, and considerable experience is essential in the formulation of uniform high-quality glues.

Casein glues are usually prepared without the application of heat, except in very special cases where recommended by the manufacturer. Cold water is placed in a mechanical mixer (50 to 70 r.p.m. paddle speed) and the glue powder slowly added, with continuous agitation, until lumps are gone and thickening occurs (usually 3 to 5 minutes). After standing idle for 15 to 30 minutes, the mix is again agitated for 2 to 3 minutes and is then ready for use.

The liquid working, or spreadable, life varies markedly for the various types that will be referred to later, but as a general rule the higher the water resistance the shorter the life. Also, the abrasiveness of the set glue line is greatest for the more highly water-resistant grades.

Casein glues, when stored under dry, cool conditions possess good keeping qualities - well over a year for the highly water-resistant grades and from 3 months to a year for the less water-resistant grades. Their durability has been conclusively proven during the 30 some years of use in the United States with supporting evidence from Europe where casein-glued building arches, etc., glued over 30 years ago are still in good condition today.

In general, they set moderately fast, yet allow an adequate assembly period. They require only moderate pressures for good bonding.

OUTSTANDING ADVANTAGES

Unlike urea resins they exhibit good resistance to heat, and satisfactorily bond woods at low moisture content. The optimum moisture content range is 5 to 8 percent, but stock as low as 2 percent and as high as 18 percent provides a satisfactory glue line. Another outstanding factor is that casein glues are much less sensitive to temperature than synthetic resins, being capable of setting at considerably lower temper-

[1] Presented at meeting of Forest Products Research Society, Northeast Section, York, Pennsylvania, May 22 and 23, 1952.

atures. Most types will set at a temperature almost as low as the freezing point of water, but the rate of setting is much slower than at normal room temperature. Thus they are ideally suited to field assembly and repair work where the prevailing temperature cannot be controlled.

Being alkaline, casein glues tend to break down the oily film present on woods such as teak, pitch pine, ponderosa pine and yews which prevents most neutral or acidic glues from getting "bite". This factor renders them well suited to the bonding of these species which are not readily bonded with a number of the other adhesives.

Casein glues possess a fair degree of "gap-filling" ability and poorly fitting joints can be bonded with only a moderate loss of strength compared with perfectly mating surfaces. This is not the case with certain other adhesives, such as most conventional urea resins.

LIMITATIONS

Owing to their alkalinity, most casein glues tend to stain wood, with the highly water-resistant grades being the worst offenders. Even the most non-staining grades impart some discoloration, which is not the case for certain neutral or acid synthetic adhesives. Also, even the least abrasive formulations, when completely set, require frequent sharpening of cutting tools.

Since casein is a protein it is subject to deterioration when exposed to mold and fungus growths. However, through the incorporation of a preservative, now standard for many grades, this weakness has been largely overcome.

Casein glues require a relatively heavy application of the glue-mix, since the major ingredient is water. Spreads from 60 to 110 lbs. per 1,000 sq. ft. single glue line are generally recommended, depending upon the construction being glued. This is often objectionable in assembling thin veneers.

SPECIFIC TYPES AND THEIR USE

For the purpose of this discussion, it seems desirable to divide the available types of casein glues into four typical classes, and for clarity their different properties are detailed in Table 1.

Class I.-Grades meeting the requirements of Government Specifications, such as Federal Spec. C-G-456, fall in this group and are recommended wherever maximum water resistance is desired. Typical uses are the fabrication of laminated rafters, prefabricated house construction, field repair of aircraft, etc.

Class II-General purpose grades which have played such a large part in the success of our sash and door industries are grouped here. Where pine is the chief species in the cores of solid flush doors this class is still in extensive use. Other typical uses are for curved chair seats and backs, butcher blocks, pattern work, the "unseen plywood" in case goods and general "mill-work".

TABLE 1--CHARACTERISTICS OF PRINCIPAL CLASSES OF CASEIN GLUES

Class:	I	II	III	IV
Common use:	Aircraft repair, rafter laminating, govt. spec. work	Sash and door work, plywood, general purpose	Furniture plywood (fancy veneers)	Assembly gluing, solid furniture, cabinet work
Storage life, years	1+	1/2 to 1+	1/2 to 1+	1/3 to 1
Contain preservative	invariably	seldom	no	no
Contain filler	seldom	usually	invariably	invariably
Dissolved cold	yes	yes	yes	*
Water per 1 lb. powder	1-7/8 to 2-1/8	1-7/8 to 2-1/8	2 to 2-1/4	2-1/8 to 2-1/2
Working life, hrs.	4 to 8	6 to 10	8 to 12	16 to 168
Spread, lbs/M sq. ft.	70 to 100	70 to 110	60 to 80	70 to 90
Max. assembly time, 75°F.	20 min.	20 min.	30 min.	40 min.
Pressure, lbs/sq. in.	50 to 250	50 to 250	50 to 250	50 to 250
Min. pressure period, hrs.	1/2 to 5	1/2 to 5	2 to 7	3 to 8
Dry strength	medium high	medium high	high	high
Water resistance	high	high	moderate	fair
Staining tendency	considerable	considerable	mild	very mild
Abrasiveness	considerable	considerable	mild	very mild

* Warm water is recommended for certain grades (up to 100° F.), but no further heating is advisable.

Class III-The grades recommended for the manufacture of fancy veneered furniture panels, and general purpose furniture plywood fall in this group. They are usually so formulated to plug the pores of the veneers and minimize bleed-through.

Class IV-In this group fall the casein glues recommended for general furniture assembly and the like, such as doweling, edge gluing of solid stock, laminating solid stock etc. These grades are the least staining from the standpoint of glue-line discoloration. They are lower in water resistance in comparison to the other groups, but are considerably superior to animal glue in this respect.

COMMON CAUSES OF FAULTY GLUE-LINES

a) Plywood characterized by spotty adhesion.
   1. Improper glue mix (incorrect weighing of the ingredients, foamy mix due to high speed mixing, lumpy mix due to failure to follow mixing directions).
   2. Improper spread of adhesive (too light, nonuniform).
   3. Improper assembly time (too long for the prevailing conditions).
   4. Improper pressure (inadequate for the type of construction, nonuniform or unequal over the entire area, improper calibration of press).
   5. Improper pressure period (too short for the prevailing conditions such as temperature, humidity, type of construction, etc.).
   6. Improper condition of the veneers (unclean surfaces, nonuniform thickness, poorly cut, rough or "washboard" surface).

b) Substandard glue-lines in fabricated stock.
   1. Faulty wood (unclean surface, warped, cupped, twisted, nonuniform in thickness, "burnished" surface due to dull planer knives, case-hardened from improper kiln drying).
   2. Faulty glue (improper glue for the species involved, improper glue mix - see above).
   3. Faulty use (spread, assembly time, pressure, pressure period, maturing period).

HELPFUL HINTS IN THE USE OF CASEIN GLUES

1. Surfaces to be glued should be smooth, flat, free of dirt, grease, paint, sealers, etc., which prevent proper glue penetration.
2. Casein glues can be hand spread with a stiff vegetable-fiber brush, machine spread with a rubber or metal roll with a rubber or metal roll with relatively coarse corrugations, sprayed, or applied with a "flow gun".
3. Assembly time is shortened by (1) thin mixes, (2) light spread, (3) soft or dry woods. The glue should be moist or tacky and should squeeze out all around when pressure is applied. On hard woods, 5 to 10 minutes open assembly gives better penetration and prevents excessive squeeze-out at high pressures.
4. Sufficient pressure should be applied to bring adjacent surfaces into intimate contact (usually 50 to 250 pounds is sufficient, depending on the conditions). A uniform squeeze-out should show along every glue joint.
5. Usually, pressure may be released when the squeeze-out has become hard and bone-like. Pressure periods may be shortened by using (1) a quick-setting grade, (2) heavy glue mix, (3) alcohol (substituted for part of the water), (4) maximum assembly time, (5) heated wood, and (6) a warm-storage room or cabinet to hold glued objects while curing.
6. Liquid life is shortened by high temperatures. In hot weather, circulation of cold water in a jacketed mixer lengthens liquid life.
7. Proportions of water can be decreased or increased by 1/8 to 1/4 lb. to produce slightly heavier or thinner mixtures. Heavy mixes are used for end grain, mitred, scarfed or loose-fitting joints, for rough surfaces, or to minimize squeeze-out on soft, porous fiberboard, etc. To prevent lumping, always make a standard mix first, then thin it out as required.
8. The use of up to 1/4 part alcohol in place of 1/4 to 1/2 part water will minimize foaming tendency, aid penetration of glue into dense woods and speed the set.
9. To reduce abrasiveness or increase flexibility of glue line, add up to three parts glycerine or up to 5 parts motor oil (S.A.E. 50) to 100 parts of glue powder (after mixing). This may change the viscosity of the glue and should be used only when necessary. The use of slightly less water may be necessary. Abrasiveness can also be minimized by machining joints as soon as joints are strong enough. Abrasiveness increases as the glue line ages.

10. Follow mixing directions supplied. The use of colder water slows the dissolving of the glue. Warmer water speeds dissolving but shortens the liquid life. If the glue does not dissolve when mixed as directed but remains granular and sandy, it is over aged and should be discarded.
11. Mold inhibitor can be added at the time of mixing to most regular grades that do not already contain a preservative. A typical additive, as required by certain government specifications, is 3 to 5 percent pentachlorophenol (based on the weight of dry glue powder) stirred into the water. However, this is apt to thicken the mix somewhat, and shorten the usable life.

UTILITY

Casein glues are nationally distributed as a packaged item (from hardware stores and building supply houses) which place them at the disposal of the home owner, home work-shop enthusiast, small cabinet maker, schools, the shops of small factories, etc. These are so formulated that they can be quickly and easily mixed, by hand, by measure rather than by weight. The continued success of this commodity testifies to the "fool-proof" nature of casein glues for general purpose use.

3. Phenol and Resorcinol Adhesives[1]

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INTRODUCTION

Realization of the great service rendered to mankind by glues of animal origin over literally thousands of years and their continued widespread use serves to remind us that assembly adhesives of thermosetting synthetic base are mere youngsters.

Assembly gluing embraces all adhesive bonding of wooden members in other than flat bed presses. This would exclude, accordingly, plywood manufacture and the production of wood-waste boards. More specifically, assembly gluing is the joining together of wooden members of greater than veneer thickness to form useful articles.

The excellent cold and hot presses used in the plywood industry combined with the thin veneers usually employed make the plywood operation ideal for the use of thermosetting resin adhesives.

The irregularity of shape of articles produced by assembly gluing, the more rigid wooden components and the thickness of these components set limitations on assembly gluing techniques which require adhesives of highly specialized character. We cannot provide economically for the distribution of pressure as uniformly as can the plywood maker. Thus, the ideal thin glue lines obtainable in plywood are not universally attainable in assembly work. Contact heating through the various thicknesses of wood employed cannot usually be economically provided. Too high jig face temperatures must be avoided if the wood is not to suffer from too much local heat. Hot chambers with humidity control or infrared or radio frequency energy are our tools for acceleration of cure. Intermediate curing temperatures below the boiling point of water are mandatory for protection of the wood. Much work must be done at temperatures as low as 70° F.

A very large portion of the failures of thermosetting adhesives in assembly gluing has been due to the use in this work of adhesives designed for the more nearly ideal conditions of the plywood mill. The majority of the adhesives sold for assembly gluing as late as 1942 or 1943 were simply adaptations to assembly work of adhesives which had performed successfully in the flat-bed press.

I will try to make you familiar with the products which have been designed specifically for the more difficult job of assembly work.

UREA FORMALDEHYDE ADHESIVES

Although phenolic adhesives in both film form (Tego film) and liquid spread form appeared in the early thirties in American plywood plants, the high temperatures required for their cure and the relatively high pressures necessary to cause sufficient flow in film types, made them unsuited to assembly gluing.

The first thermosetting adhesives introduced to the American woodworking industry for assembly gluing were urea-formaldehyde liquid resins imported from Germany. These early imports, although far inferior to our present day urea-formaldehyde adhesives, served to inspire American resin manufacturers to develop improved urea-formaldehyde formulations.

The German offering was a neat liquid urea-formaldehyde syrup with a chemical hardener to be mixed with the syrup immediately prior to use. These adhesives were characterized by intolerably short storage life, inadequate viscosity to remain in the glue line and extremely high acidity of the cured film.

American manufacturers, seeing the potential of these resins for cold press plywood manufacture, rapidly developed improved materials aimed particularly toward the plywood field. These adhesives had many properties to recommend them:

1. They set to a highly water-resistant bond at temperatures as low as 70° F.
2. Their shelf life of about three months was commercially tolerable.
3. They were extendable with wheat flour which, in moderation, served to improve their bonding properties by

[1] Presented at meeting of the Forest Products Research Society, Northeast Section, York, Pennsylvania, May 22 and 23, 1952.

retaining the adhesive in the glue line. Further extension with cheap cereal flours provided bonding of water resistance superior to tapioca bonds at very nominal cost.

4. They were colorless and non-staining and hence were highly acceptable for the gluing of light exotic woods.

5. They could be formulated for either cold press or hot press use.

In the late thirties, spray drying of these syrups provided dry powder adhesives of excellent shelf life. Spray drying opened the way to the production of precatalyzed dry powder adhesives which required only to be mixed with cold water to be ready for application. These "one-package" dry powder adhesives were very acceptable to the assembly gluing industry because of their simplicity of use. At least two brands of this type adhesive improved through the years have found wide distribution in small packages through hardware and general supply stores.

By 1942, the value of urea-formaldehyde adhesives, as well as some of their shortcomings, were recognized by the promulgation of a military specification regulating their quality for aircraft gluing. Specification ANG-8 is familiar to all of you.

One of the shortcomings to which attention was drawn was the undesirable effect on durability of the use of starchy fillers. These amylaceous fillers were susceptible to hydrolysis by the acidic catalysts and were further rather welcome spots for bacterial and fungus attack. Inert fillers comprising wood flour or walnut shell flour proved more suitable. The specification also regulated the extent of filler use to that addition which was recognized as beneficial, and proscribed the adulterative practice of extension ad absurdum.

Another contribution of the government specifying laboratories was the regulation of the degree of acidity developed in the cured glue film. This was set at that time at a pH of 2.5 at which value room temperature cure could be effected with minimum potential damage to fibers adjacent to the glue line.

Adhesives formulated to meet ANG-8 were very widely used in Canada and the United States for a great variety of military assembly work.

A further development which, in the opinion of many, has been significant to the improvement of urea-formaldehyde assembly adhesives was made in England in 1942.

Both British and American workers had observed the high sensitivity of the urea-formaldehyde adhesives to glue line thickness. Whereas in ordinary service, conventional urea-formaldehyde adhesives showed good retention of bond strength as tested both dry and wet when glue lines were made thin (.002 to .007 inch) as in plywood manufacture, there was a noticeable deterioration of bond strength when glue lines on the order of .015 to .020 inch were made.

The British ministry of aircraft production strongly desired to adopt urea-formaldehyde adhesives in place of casein glues which had shown up rather unsatisfactorily in aircraft that had to be stored outdoors. Realizing that fitting to assure minimal glue line thickness could not be achieved in their wooden aircraft production, they called upon their resin manufacturers to develop adhesives that would remain strong in glue lines up to .020 inch. Several successful modifications were made. Of these, one outstanding formulation utilized benzyl alcohol as a part of the liquid phase. This adhesive not only provided improved strength and strength retention in thick glue lines, but also was capable of making small castings which remained uncrazed long after similar castings with conventional urea-formaldehyde resins had crumbled.

Adhesives based on this formula were very successfully used in both Englad and Canada in the extensive wooden aircraft programs. The Mosquito, fastest aircraft of the pre-jet day, was produced in quantity using this improved urea-formaldehyde formulation.

Recognizing the superiority of craze resistant adhesives, one American producer, having made the English type benzyl alcohol modification for Canadian use during the war, indulged in an extensive research program to develop a more economical and better craze resistant adhesive for the American market. This work, now protected by patents, resulted in the adaptation of furfuryl alcohol as a modifier and the production of a superior adhesive of excellent bonding quality and craze resistance.

This type of adhesive is now available from several American suppliers. Its growth over the last eight years demonstrates the acceptance of the margin of safety it provides against the unavoidable occasional thick glue line encountered in assembly work.

Any manufacturer contemplating production of an assembly using urea-formaldehyde adhesives has a wide choice of top quality products in either conventional or craze-resistant materials.

In closing our consideration of urea-formaldehyde assembly adhesives, let us point up their advantages and shortcomings.

They provide room temperature or elevated temperature cure.

They are non-staining and highly color stable.

They are quite resistant to cold water and are generally considered suitable for any service other than outdoor exposure or continuous service at high temperature (over 140° F.) or combined high temperature and high humidity.

They are not, however, as durable under all conditions of service as are bonds made in the hot press using phenolic or melamine adhesives.

Because of their desirable gluing properties and their freedom from color, urea-formaldehyde adhesives will continue to be very widely used in assembly gluing for all but extreme service conditions.

ACID CURING PHENOLIC ADHESIVES

Of the assembly adhesives that we find in use today, the acid curing phenolics made their appearance shortly after the urea-formaldehyde materials had achieved popularity.

In quest of the goal of finding an adhesive capable of setting at room temperature or mildly elevated temperature, having application properties suitable for assembly work and providing in assembly gluing techniques bonds as durable as those produced in the hot press with phenolic resins, two American producers introduced, in the early forties, adhesives based on acid curing phenolic resins.

The early prototypes of this category were caused to set at temperatures easily attainable in assembly work by the admixture of such quantities of strong acid hardeners that the glue film pH fell considerably below the minimum 2.5 value then held to be the permissible minimum for durable gluing for military use.

The appearance shortly thereafter of alkaline setting and then neutral setting low temperature adhesives which made possible more rigid limitation by military specification of glue line acidity, impeded development of adhesives of this category.

We now know, however, that adhesives based on acid curing phenolics were widely used in Germany during and before the war with reputed high success. In the last few years, formulations of much moderated acidity have appeared. The advent of more general use of intermediate curing temperatures around 150° to 180° F. has opened up a field for such adhesives in which they are finding increasing acceptance. Of particular interest is the success these materials have met in curing at high frequency. Their relative freedom from arcing in radio frequency cure, places them in an unique category among assembly adhesives of phenolic base.

Another property which some products of this class exhibit is excellent color.

Although acid-curing phenolic adhesives have many properties which encourage their use in assembly gluing, their limited shelf life presents a serious handicap to their sale in competition to other established assembly adhesives.

These materials have not enjoyed widespread use. Depending on final proof of their durability, we may expect to see markedly greater use of these unique adhesives.

PHENOL-RESORCINOL AND RESORCINOL-FORMALDEHYDE ADHESIVES

Urea-formaldehyde adhesives and acid-curing phenolic adhesives provided handy means of producing a wide variety of wooden assemblies of vastly greater serviceability than animal glues or casein glues. The use of adhesives in the production of PT boats and other laminated marine and aircraft assemblies for World War II brought about critical study of the durability of adhesives by military and other government agencies as well as by industry.

Experience had taught that bonds produced in hot pressing with alkaline phenolic-resin adhesives remained as durable under the most abusive conditions of service as did the wooden components which they joined. The assembly adhesives already discussed at their state of development in 1940 and 1941 indeed left much to be desired in comparison to the bonds produced by hot-press phenolics.

The adhesive industry met the challenge and developed an entirely new synthetic-resin adhe-

sive system which provided, in assembly gluing techniques, bonds of such high indicated durability as to warrant their immediate acceptance for durable gluing of military structures.

Assembly adhesives based on resorcinol-formaldehyde resins and on phenolic resin made curable at lower than hot-press temperatures by incorporation of resorcinol made their commercial debut in 1942.

The high reactivity of resorcinol-formaldehyde had been recognized about the mid-twenties and a patent application of 1926 disclosed the use of this system at low pH in the manufacture of compression molding compositions.

Recognition of the high reactivity of resorcinol-formaldehyde resins at alkaline or neutral conditions is responsible for the development of adhesives which have found wide use in assembly gluing and provide at room temperature, or preferably mildly elevated temperatures, wooden assemblies as durable as the wood from which they are made.

The urea-formaldehyde and phenolic adhesives described previously are made with their full requirement of formaldehyde. The reaction is arrested by adjustment of pH to a value at which the system shows little enough reactivity to provide commercially tolerable storage life. Reactiviation of the system is provided by adjsutment of the pH at the time of mixing before use to a range that provides the desired reaction velocity for use under the desired conditions.

Although the reactivity of resorcinol-formaldehyde resins is sensitive to changes in the acid-alkali balance, there is no pH at which the reactivity of resorcinol-formaldehyde resins is so low that chemically complete formulations can have tolerably satisfactory shelf life. The system adapted to rectify this condition provides us with highly reactive formulations possessing shelf life substantially greater than most other assembly adhesives. In fact, some straight resorcinol-formaldehyde resin adhesives remain useful for many years.

To provide this stability, the resin reaction is carried out with a definite deficiency of formaldehyde. The incomplete condensation product is then adjusted in pH to the desired range for use. Either para-formaldehyde or 37 percent formalin is added at the time of mixing for use to complete the requirement for formaldehyde.

Straight resorcinol adhesives, as well as the majority of phenol-modified resorcinol adhesives, are capable of curing at room temperatures (minimum 70° F.) to provide bonds equal in demonstrated durability to those produced by phenolic adhesives in hot pressing.

For the gluing of certain species, such as oak for ship members, the Bureau of Ships has widely prescribed minimum cure at controlled mildly elevated temperatures.

The capability of resorcinol adhesives and phenol-modified resorcinol adhesives of setting at neutrality or on the mildly alkaline side, provides assured freedom from catalyst attack on wood fibers. These adhesives have made possible the establishment of such specifications as JAN-A-397 now superseded by MIL-A-397. The judicious application of these specifications has greatly furthered the production of durably glued wooden assemblies. Much credit is due to the Bureau of Ships and the Bureau of Aeronautics for furthering the development and improvement of these adhesives.

In spite of the excellent durability of assemblies made with these adhesives, they possess as a class, two properties that limit their wide adaptation.

One serious handicap is the inherently high cost of the chemical resorcinol. New developments in the methods of modification of resorcinol resins with phenol are making possible reductions in price of some formulations to closely approximate the cost of the acid-curing phenolic adhesives.

The second disadvantage of this class of adhesives is their inherent wine red color which inhibits their acceptance in many applications involving the gluing of light decorative woods.

In freedom from sensitivity to the glue line thickness, resorcinol adhesives approach the craze-resistant urea-formaldehyde types. Work is under way to provide these highly durable adhesives in gap-filling or craze-proof modifications. Present representatives of this class of adhesives are suitable for maximum glue line thickness of .007 to .015 inch, depending on the species of wood being glued.

In all, we can say without fear of contradiction that resorcinol-formaldehyde adhesives and their properly made phenol modifications are, at present, the most durable waterproof adhesives available for curing under conditions obtainable in assembly gluing.

MELAMINE-FORMALDEHYDE ADHESIVES

A fourth chemical group of adhesives are those based on the reaction product of melamine with formaldehyde. Melamine adhesives are capable of being cured at hot press temperatures without admixture of potentially detrimental acidogenic hardeners to provide colorless, stainless bonding of durability equal to that of resorcinol adhesives. Formulations for low-temperature or intermediate-temperature gluing have all required some addition of acidogenic materials. To date, there has been little acceptance of melamine adhesives in assembly work. Further investigation may provide colorless adhesives capable of the highest performance.

CONCLUSION

With the cooperation of the woodworking industry, the military, and the Forest Products Laboratory, the chemical industry is intensively studying the field of assembly adhesives. A wide choice of formulations is availabe today to meet most requirements of the industry. Research is in progress to improve the properties of these synthetic adhesives and to bring into being chemically new adhesives.

Most manufacturers are working very closely with the major laminating programs. Your supplier has studied the peculiarities of his formulations and can render very helpful technical service.

If the chemical industry can impart to its thermosetting products the capability of bonding in short clamping time, which is characteristic of animal glue, the field for these adhesives will be magnified many times. As it is now, thermosetting assembly glues have expanded the applicability of gluing to greater fields of service, but have not seriously cut into the markets for animal glues.

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4. Urea and Melamine Adhesives[1]

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INTRODUCTION

Resin adhesives are no longer something new or a material to be handled with fear. They have come of age and can be utilized successfully in production when the user is aware of their characteristics and limitations. As with any established product, the developmental sales approach must be terminated. The product is now a highly competitive item from the sales standpoint.

It will, therefore, be the purpose of this paper to acquaint you with the basic pertinent properties of resin adhesives and to emphasize the importance of awareness of these properties in selection and application of your adhesives.

UREA RESINS

Of greatest importance in the hardwood plywood field the urea resin adhesives account for the major portion of resin adhesives produced today - Department of Commerce figures for 1951 show that 76,200,000 pounds of urea and melamine adhesives were produced as compared with 39,600,000 pounds of phenolic adhesives in the same period. These figures are based on solid resin.

Urea resins are produced from crystal urea, a nitrogen derivative, and 37 percent formaldehyde in aqueous solution. The urea and formaldehyde are charged to a kettle equipped with agitators and facilities for heating and cooling. The ingredients are added in a predetermined ratio generally in the range of 1.5 to 2.2 moles of formaldehyde for 1 molecular weight of urea. The reaction is carried out at elevated temperatures with agitation and the pH of the solution is maintained on the acid side through the addition of acid or acid salts. During the preliminary stages of the reaction and even at room temperature the urea and formaldehyde react first to form monomethylol urea and then dimethylol urea. Both products will crystallize when the solution cools, both are very water soluble, and the molecular size is small. These properties yield a product which would be suitable as am impregnant, but a product which would cure slowly because the degree of polymerization is slight. As the reaction progresses, the polymer size increases until a desired size is obtained and the reaction is discontinued. The urea formaldehyde polymer or resin, as it is generally known, may be shipped in the liquid form or may be spray dried and shipped as a powder. Because, as we have indicated, the reaction of urea and formaldehyde progresses at room temperature, resins in the liquid form continue to react during storage at a greater rate than do the powdered resins, hence the shorter storage life of the liquid materials.

To digress momentarily, there is one point which should be emphasized. Urea formaldehyde resins are not only produced for adhesive use, but also find application as ingredients in finishes (primarily the baking enamels) and as thermosetting molding materials. In each of these applications, however, the ratio of urea and formaldehyde is altered and other materials may be added to enter into the reaction. Generally speaking, these resins are water insoluble and the polymer size is large even though such general properties as catalysis, cure temperature, etc., are typical of the urea type resin.

Storage life of the resin is generally an arbitrary value established by the manufacturer. In strictest terms, the end of the storage life is not necessarily that point at which a liquid resin becomes a gel or a powder is completely insoluble in water, rather it is a point at which the viscosity and the reactivity are considered to have exceeded the limits within which the resin can be recommended for general use. There are innumerable instances wherein resin, considerably in excess of recommended viscosity and reactivity, has been satisfactorily used. In these cases, conditions of use are within the general limits suggested by the manufacturer. Had conditions exceeded the limits unsatisfactory performance would be expected with the over-aged material whereas resin within the recommended storage limits would be expected to tolerate conditions somewhat beyond the normal.

Cure of urea resins is effected in two ways, through the use of heat and with acid catalysis. One condition alone is inadequate for optimum cure. Temperatures of 70° F. or higher are required and the extent of catalysis or the degree to which the acidity, expressed as pH, of the mix must be lowered varies inversely with the temperature. Cure of urea resins at temperatures below 70° F. cannot be considered as conducive

[1]Presented at meeting of Forest Products Research Society, Northeast Section, York, Pennsylvania, May 22 and 23, 1952.

to optimum results. Usually, the resin dries out, through a loss of water to the wood, before the polymerization has proceeded far enough to permit formation of a continuous film of resin. A glue line cured at inadequate temperatures has a grainy or sandy appearance and texture.

At normal hot press temperatures of 240-260° F., a urea resin can be cured when only slightly acid or when the pH is just below a value of 7.0. Practically all liquid resins and some powdered resins are alkaline as supplied. This alkalinity contributes to superior storage characteristics but must be adjusted when the resin is prepared for use. There are resins which are converted from an alkaline pH to an acid pH by the acids in the wood. More generally, however, optimum results are obtained if the pH is adjusted through the addition of an acid salt or combination of salts.

The most generally used acid salts are those with the ammonium group, such as ammonium chloride or ammonium sulfate. Ammonium chloride is in widest use either alone or in combination with other materials. Preference for ammonium acid salts is based on the fact that the salt ionizes to yield ammonium hydroxide and the acid of the salt. The buffering effect, or control of the rate of catalysis by the ammonium hydroxide allows for closer control of the rate of reaction than is possible with other types of acid salts. It is important to note that the amount of acid salt added is not necessarily directly proportional to the reactivity of the resin mix. It may be inversely proportional beyond a certain point. This effect is due to the ionization of the salt to form the alkaline hydroxide which offsets the effect of the acid liberated during the ionization.

Resin manufacturers recommend specific catalysts or hardeners for use with their resins. Contrary to general belief, these catalysts are not usually simple acid salts, rather they are a blend of materials designed to give optimum working properties and bond quality. When a plant is able to sacrifice some of the working properties of its adhesive or possibly to modify the bond quality, most manufacturers are able to furnish specific data regarding behavior of their resins with the commonly used acid salts. For special applications, however, this procedure is not suggested.

Another material that finds use in catalyst formulations is ammonium hydroxide which permits pH control and allows for subsequent control of reactivity of the mix at room temperature. One of the desirable features of ammonium hydroxide is the fact that it is stable at room temperature, and permits a long working life, but at elevated temperatures the ammonia volatilizes rapidly permitting an almost instantaneous reduction in pH which, of course, results in rapid cure of the resin.

Crystal urea behaves in a manner similar to ammonium hydroxide in controlling resin reactivity except that, of course, it is not a basic material and it is not volatile. The crystal urea combines with the free or loosely bound formaldehyde in the resin, limiting the amount of formaldehyde available for the polymerization reaction. As a result of this combining of urea and formaldehyde small resin polymers are formed which, of course, have a slow rate of reactivity. The overall effect, then, is to retard the reactivity of the resin mix. The added advantage of this reaction is the increase in thermal flow of the resin allowing for the use of longer assembly periods.

Lubricants, such as zinc stearate, are often found in catalyst systems particularly for tapeless splicer applications.

FILLERS AND EXTENDERS

Considerable question exists in the mind of resin users as to the value of fillers. First, consider the function of a filler. Its primary function is to control resin flow. The term resin flow describes the movement of resin into the wood or laterally in the glue line. Flow of the resin into the wood is probably more accurately described as penetration but in the discussion of fillers we will assume flow to mean perpendicular as well as lateral movement of the resin in the glue line.

A filler is any material which will control flow of resin that is due to pressure and/or heat. Most commonly used fillers are nut shell flour and wheat flour. The nut shell flours such as walnut shell and pecan shell have gained wide acceptance because of their efficiency. A few resins can be controlled as effectively with wheat flour as with shell flour.

The maximum amount of filler will vary with the resin, but will fall in the range of 5 to 20 percent, based on solid resin, in most cases. It has been established that most resins will develop optimum strength and water resistance when filler is employed. It is of particular importance to note that the neat or unfilled resin has lower strength and wood failure than the same resin with the proper amount of filler. The need for filler can be determined by a glue line examination. If bleed through is not of importance, there should be adequate glue in the

glue line after pressing and the flow and transfer must have occurred to the proper degree. In other words, 100 percent wood failure would be anticipated. If wood failure is shallow or sparse and if inadequate glue is evident in an examination of the glue film, excessive flow has occurred and more filler is required. Conversely, if the film is thick, flow has been inadequate and excessive filler has been employed. In attempts to reduce bleed-through it is occasionally desirable to sacrifice slightly on bond quality and maintain a thicker than normal glue film through the use of larger than normal amounts of filler.

Extenders are not to be confused with fillers. Their sole function is to reduce cost. Most common of the urea resin extenders is wheat flour largely because of its low cost and availability. Rye flour and even corn flour are used, but to a much smaller degree than wheat flour.

Certain varieties of wheat cannot withstand the cold of the winter season which prevails in some parts of the country and therefore are planted in the spring. Other varieties are more hardy and are planted in the fall. Even within the boundaries of one state, there is an appreciable difference in the character of the wheat. At least 200 different types and varieties of wheat flour are known. These types may be classified into five general groups; the strong flours are high in gluten content while the weak flours are low in gluten content.

1. Hard spring wheat - It is grown in the northern states; Minnesota, The Dakotas, Iowa, Nebraska, and Northern Wisconsin where the winters are cold. It is a strong flour.

2. Hard winter wheat - It is grown in the middle states of the country south of Minnesota and the Dakotas between the Mississippi River and the Rocky Mountains. It is a fairly strong flour.

3. Soft winter wheat - These types are chiefly grown in the Central and Atlantic States and produce a weak flour.

4. White wheat - These varieties are grown on the Pacific Coast and on the western slope of the Rocky Mountains. Generally they produce the weakest flours of the five groups.

5. Durum wheat - It is grown in some southern states and Montana. The flour is strong, but it is generally not used for baking purposes.

The flour producer mills the wheat and it is blended to average the differences that exist. However, it is virtually impossible to consistently produce exactly the same product. Even though a flour is marketed under the same brand name, it will vary in its water requirement so far as the user of resin glues is concerned. This is due to the fact that the flour producer does not control the properties of the flour by blending for their use with resin glues but for other purposes such as the production of baked goods.

The crude protein content of wheat flour is reported by the mills and will be available if desired. The protein content is an indication of the amount of gluten which will be formed when water is added to the wheat flour. It is the gluten content of the flour which determines whether or not the flour is satisfactory as an extender for urea resin adhesives. A high gluten content produces a wheat flour which has a high water requirement. Quite often the high gluten is also responsible for a mixture which is not smooth. This curdy condition can be noted even in a simple mixture of the wheat flour and water. The two factors, high water requirement and curdiness may be undesirable features when the wheat flour is to be used for extending the resin glues.

Certain types of bleached and phosphated flours can cause difficulty when used to extend urea resins. Due to the treatment which they have received, they may accelerate the curing of the resin glue to a degree which impairs the bonding properties of that adhesive. It has been noted that several flours of this nature increased the setting time of a resin glue mixture as much as four times over that which would be obtained with a normal wheat flour.

HOW MUCH WATER

An apparent inconsistency in resin manufacturers' instructions is evident in the amount of water used in the mix, or expressed another way, in the solids content of the mix. Under normal circumstances there is a fixed ratio of water and resin. One resin may require 70 parts of water per 100 parts of resin whereas another will require only 50 parts of water per 100 parts of resin. This water ratio is characteristic of a given resin. When flour extenders are used, the water requirement of the flour will usually fall in the range of one to one and one quarter parts of water per one part of flour. This explanation would seem to indicate that formulations with a given resin would always be within close limits and that the plant which used 220 parts of water in a mix instead of the recommended 180 parts should anticipate trouble. Yet the quality of their production is at a high level. To explain

this, let's consider the function of water in a mix.

Basically, the resin is suspended colloidally in the water whether the resin is supplied as a liquid or as a powder which is mixed with water. The water serves as a vehicle for the resin allowing it to be mixed with other ingredients, facilitating application of the resin to a veneer surface, and provides for a complete reaction between resin molecules because of intimate contact. A secondary function of the water is to promote flow of the resin either as physical flow or thermal flow. Physical flow is not difficult to visualize if you compare the wetting properties (or flow) of molasses undiluted with the same molasses mixed with water. Thermal flow is influenced by water as it affects the rate of reactivity of the mix. A high solids (low water content) mix will react more rapidly than a low solids (high water content) mix. Therefore, on the glue line, the least reactive mix will have the greatest period of flow or the greatest flow and penetration and vice versa.

These are conditions under which the adhesive is used which necessitate a deviation from standard practice particularly as regards the solids content of a mix. Low density woods are not conducive to maximum flow of the resin mix. They tend to absorb water, readily retarding flow. This condition is aggravated at low moisture content and it is evident that additional water (within limits of course) will improve flow characteristics. In an evaluation of a resin and in establishing moisture content limits, a normal moisture content is generally considered to be 6 to 12 percent and a formulation would be determined at these moisture content limits. Veneer at moisture contents outside these limits will cause abnormal flow characteristics in the resin and to overcome the abnormalities a modification in solids content is indicated. It is possible then that the solids content should necessarily be increased if veneer moisture content is excessive.

Resin flow characteristics in the more dense species such as birch and maple are different from those encountered with the low density species in that there is a greater tendency for excessive flow. These harder woods have less capacity to absorb water from the mix and there is more water available in the glue line to influence the flow of the resin.

Alteration of the mix solids must, however, be controlled to avoid other unsatisfactory glue-line conditions. When solids are lowered to improve flow a point can be reached where excessive flow occurs and further where blistering results because of excessive moisture in the panel. At the other extreme, flow can be limited to an extent where precure or complete lack of flow results.

Changes in mix solids have one other effect - namely, to alter the working life of the mix. At high solids a shorter working life or faster gel time can be expected whereas at low solids the working life and gel period are extended.

WORKING LIFE

Instruction bulletins of the resin manufacturers usually state the working life or pot life of typical formulations. The values given, generally represent the minimum value and it is desirable to consider the value as exact. The working life of a resin mix is generally considered to be a multiple of the original viscosity. It is established at a point before which the mix can be expected to form a gel.

As has been mentioned, mix solids can materially affect working life, the other major factor being temperature. An alteration in either factor will correspondingly alter the working life. Further, values given by manufacturers are based on factors remaining constant during the stated period. If, for example, the temperature of the mix increases during the working life period, a decrease in stated working life at the initial temperature can be expected.

A rule of thumb determination rather widely used in determining working life is that for each 10° F. increase in mix temperature a 50 percent reduction in working life is to be expected -- conversely for each 10° F. decrease in temperature the working life can be expected to double. This same rule, of course, applies to rate of reactivity which is also an expression of working life but where the end point is a gel rather than a predetermined viscosity.

CONSIDERATIONS AFFECTING SPREAD

Probably one of the most abused factors in resin adhesive use is the rate of spread. There are minimum and maximum limits, i.e., 25 to 35 pounds per thousand square feet of single glue line for unextended resins or mixes with low extensions and 35 to 45 pounds per thousand square feet of glue line for the more highly extended mixes when hot pressing. In cold pressing, because there is no thermal flow of the resin which would assure proper coverage and good penetration, spreads ranging from 40 to 60 pounds are required. The spread rates are expressed in terms of pounds of resin mix per 1,000 square feet of surface. The term single glue line must not be confused with the glue lines in a three-ply panel where the value per thousand square feet must be doubled

to obtain the spread rate for the panel. The spread in both lines of a 3-ply panel is usually expressed as pounds per thousand square feet of double glue line. Note that the expression double glue line refers only to the number of glue lines, and not to double spreading where glue is applied to both surfaces of the joint.

We mentioned spread as an abused factor because: (1) Many plants, in attempts to economize, work at the lower spread limit and in the long run lose money because of a high reject rate. (2) Little or no effort is made to control spread uniformly which results in excessive glue line costs. Assume that the glue mix cost is $.08 per pound and that 35 pounds per thousand square feet of glue line is recommended as a spread rate. In a plant producing 20,000 square feet of 3-ply panels the glue line cost would be approximately $112.00 (20,000 ft. x 2 glue lines = 40,000 sq. ft. glue line. 40 x 35 pounds = 1,400 pounds of glue mix. 1,400 x $.08 = $112.00). Instead of averaging 35 pounds let's assume a plant exceeds the spread by 10 pounds or is spreading 45 pounds per thousand square feet of glue line. The glueline cost then becomes $144.00 or an increase of more than 25 percent. We do not mean to imply that spread rates should be reduced -- only that they be controlled since it is evident that reject panels can rapidly offset any small savings afforded by very low spread rates.

To determine or to control spread rate it is desirable to check sample spread pieces periodically with a gram scale. There are two methods of using a gram scale. In one case 12 inch by 12 inch specimens of veneer are first weighed, then passed through the spreader and reweighed. The difference in weight represents the amount of glue mixture applied to two square feet of single glue line. It so happens that the gram scale reading may be converted from grams per two square feet of single glue line into pounds per thousand square feet of single glue line by adding 10 percent to the gram scale reading. Thus if a 12 inch x 12 inch specimen is passed through the spreader and coated two sides and the gram scale shows 40 grams of mixture applied to this sheet, you would be applying glue at the rate of 44 pounds per thousand square feet of single glue line. The other method permits direct reading from the gram scale in pounds per thousand square feet of single glue line but requires the use of somewhat larger pieces of veneer. By using sheets of 25-1/4 inches by 12-1/2 inches the gram scale reading can be read as pounds of mixture per thousand square feet. This figure will represent pounds per thousand square feet of double glue line if the sheet is spread two sides and pounds per thousand square feet of single glue line if spread only one side. The size of the sheet sets up a conversion factor which enables you to make this direct reading. Thus, if a sheet of this size were passed through the spreader and coated two sides and the gram scale showed 80 grams of glue applied, you would read this as 80 pounds of mixture per thousand square feet of double glue line or 40 pounds per thousand square feet of single glue line. A simple formula would be:

$$\frac{\text{Grams applied}}{\text{Area sq. in. any size piece}} \times 317.5 = \text{lbs. applied (either single glue line if spread 1 side or double glue line spread 2 sides)}$$

ASSEMBLY TIME

Assembly time is defined as the time which elapses between spreading of the glue and application of full pressure. The most commonly used assembly times in hot press applications will range from 0 to 2 hours. In cold pressing, 20 minutes is generally considered as a maximum although the maximum is actually determined by the rate at which the glue dries and becomes incapable of flow and transfer.

The characteristics of a resin or a resin-hardener system have considerable influence on assembly time characteristics. Some ureas, melamines, and phenolics have exceedingly long flow characteristics and actually may not perform well at short assembly periods. The density of a veneer, the moisture content, and spread rate also play an important part in assembly time characteristics. Dense veneers usually retain more water in the glue line and tolerate longer assembly periods than do less dense veneers. High spreads are conducive to long assembly time whereas lower spreads are generally associated with short assembly periods. Dry veneer limits assembly time whereas veneer at higher moisture content tends to extend the allowable maximum assembly time.

Pressing time recommendations usually tend to be conservative and they should be because of the large number of variable factors in a plywood operation. Such factors as veneer moisture content, spread, temperature variations between platens in hot presses, aging period or hot stack, etc., all relate directly to the cure time of a resin. These are in addition to catalysis, inherent resin characteristics and mix solids which are all related to reactivity.

At veneer moisture contents in excess of the recommended limit, longer cure times are necessary because the excess moisture tends to retard the reactivity of the resin. Conversely,

dry veneer absorbs moisture from the resin, increasing reactivity. Spread rate is related to cure rate because of the moisture which is introduced by the glue mix. Temperature variations as great as plus or minue 10° F. are not uncommon between platens in a hot press and in many cases the variation may be decidedly greater. Variations over the platen area due to water pockets are also not uncommon. In cold pressing, stock temperature is of primary importance. As has been emphasized, ureas do not generally cure well below 70° F. If therefore, the stock temperature is below 70° F. the time required to attain a 70° F. temperature will lengthen the pressure period. It should be emphasized that the foregoing comment has very definite limitations inasmuch as excessively low stock temperature i.e., 50 to 60° F. or lower, is not conducive to satisfactory cold press bonds because the rate of heat transfer even in kilns may be so slow that cure cannot be satisfactorily effected before the glue dries rather than polymerizes.

As a general statement, any factor which influences the reactivity of the resin mix will likewise affect the cure time requirement.

The characteristics of urea resins are very similar to those of melamine resins with possibly one major exception. Melamine resins are limited to use at temperatures above 120 to 140° F. Attempts at development of catalyst systems which will permit cure over a range of temperatures directly comparable with ureas have been unsuccessful.

Phenol formaldehyde resin adhesives are used only in limited amounts in the hardwood plywood field and for this reason we will touch only briefly on their characteristics.

Phenolic resins are usually a reddish to reddish brown color and are alkaline type materials in contrast to the acidic urea and melamine resins.

Some phenolics have been developed which have assembly time characteristics similar to those of the urea resins but these are usually exceptions. Fillers are required, but extenders are seldom used. Cure temperature requirements are generally in excess of the urea and melamine temperatures.

The dark color of the phenolic resins has been a major objection in the hardwood plywood field and particularly in the furniture panel field when face veneers are used. The one exception to this is tego phenolic film which still finds use as an adhesive for two-plying thin fancy faces.

Our comments regarding phenolic adhesives have been restricted to the hardwood plywood field. In the Douglas-fir industry the phenolics occupy a number one position and the urea and melamines occupy a secondary position so that in the overall adhesive picture phenolics play a very important part.

It is obvious that our discussion has been based largely on urea resins. We do want to emphasize, however, that the basic characteristics of ureas are, except as we have just noted, essentially the same as the melamines, phenolics and resorcinols. The information given to you is designed to assist you in handling and using resin adhesives in general with the emphasis on urea resins.

SELECTION OF RESIN FOR MAXIMUM DURABILITY

We should now consider the selection of an adhesive or an adhesive formulation for maximum durability, which is needed for unprotected exterior exposure in applications such as housing, marine and aircraft use or for interior applications where exposure conditions are extreme, i.e., paper mills, laundries, etc. There are three resins to be considered:

Melamine - A colorless, resin similar in most all respects to urea resins and used in combination with urea under normal urea operating schedules. Its apparent disadvantage of high cost is more than offset by its excellent tolerance of normal operating characteristics which results in a uniformly high level of quality.

Phenol - A hot press resin with characteristic red to red brown color -- generally limited to structural plywood rather than for thin fancy faced furniture panels.

Resorcinol - The only cold-press resin which will produce a completely waterproof bond. Red to red brown in color but otherwise handled essentially the same as a cold-setting urea resin.

RESINS FOR INTERIOR USE

For a quality interior panel or a panel to be used in a protected exterior application, unextended urea resins are recommended. The classification of unextended will generally include about 25 parts of flour.

Since this paper has been devoted primarily to urea resins, let us consider the properties of this resin type in greater detail.

As has been indicated, urea resins unextended produce a high quality, highly water resistant bond. They are not classed as water proof resins because continued wet and dry exposure will degrade the bond. On continued immersion in water, however, degradation of the bond occurs at a slow rate indicating a high degree of insolubility of the cured resin.

Elevated temperature in combination with high moisture content or high humidity is the greateast enemy of urea resins. During the past war, a test was established for lend-lease plywood which was designed to eliminate urea bonded plywood--or at least to establish only ultimate quality in urea-bonded plywood. Realizing that ureas were sensitive to elevated temperature in the presence of moisture, the specification test required immersion of plywood in water at 145° F. ±5° F. for 3 hours. The critical temperature for the resin is actually 149 to 150° F. As a further example of the sensitivity of urea resins to these conditions, we might cite the case wherein a processor of plywood was redrying cold-pressed urea-bonded plywood at temperatures of 180° to 210° F. for 24 to 48 hours. Because the panels were cold pressed the moisture content ranged from 14 to 18 percent (which is high but not abnormal for thin cold-pressed panels). At the end of the redrying period, considerable blistering and delamination was evident in the plywood, not because the panels were improperly bonded, rather because the urea resin had been degraded by a combination of high moisture and high temperature. To avoid this situation, lower redrying temperatures are indicated. A natural question would concern the degradation due to hot pressing. The essential difference is that cure is being completed during the hot press cycle. A cured bond is not being exposed to high heat and high moisture. Continued exposure of the panel to the heat of the press does not result in degradation of the bond (within limits) because of the absence of high moisture.

ECONOMICS OF EXTENDER USE

One of the major advantages of urea resins, their compatibility with low cost extenders, can also be considered a disadvantage. Generally speaking, most plywood producers tend to use excessive flour extensions in order to reduce costs. This is done without knowledge of the effect on bond strength, or with the opinion that the bond is adequate.

Another consideration relative to flour extensions is cost. Consider the following hot press formulations:

Resin at $.20 per lb.	100	100	100	100
Flour at $.05 per lb.		25	50	100
Water	60	85	115	175
Cost per lb. of mix	$.125	$.101	.085	.067
" 25 lb. spread	$3.12	$2.53	-	-
32 lb. spread	-	3.23	2.72	-
40 lb. spread	-	-	3.40	2.68

As flour extender is increased, spread requirement is increased. We have, therefore, given costs at the required spread and it is evident that one of the cheapest formulations to use is the mix extended with only 25 parts of flour. This is a formulation which most resin manufacturers will agree represents a high quality urea adhesive. With the current low prices of urea resins the gap between resin and flour costs is narrowing to the point where savings effected by high flour extenders are rapidly approaching zero.

Discussion

QUESTION: A plant making oak seat bottoms warms their stock prior to gluing to theoretical 80° F. by laying pieces edgewise on hot plates over steam pipes. The hot animal glue is mixed and applied correctly. Some joints fall apart from starvation. What is the mistake?

R. TUTT, JR.: Laying the joint faces to be glued in direct contact with hot steam pipes for the purpose of warming the stock to 80° F. excessively heats those faces to a temperature somewhat in excess of 80° F. The procedure also upsets moisture balance in stock due to excessive drying at faces, with some distortion and case hardening. To bring the temperature of stock for gluing into equilibrium with a warm glue room it is safer to condition it stickered on trucks, prior to surfacing, thus avoiding case hardening, unbalanced moisture content, and surface distortions.

QUESTION: A plant edge glues yellow poplar core stock into panels with hot animal glue. Within 3 to 4 hours after removal from clamps some of this stock is veneered in conventional hot press equipment using a resin. Some cores open up in joints. What is wrong with technique?

R. TUTT, JR.: Processing core stocks edge glued with animal glues within 3 to 4 hours after removal from clamps does not permit sufficient time for the cores to come to correct moisture equilibrium of 6 to 8 percent. The percentage of moisture at and near glue line is too high at that time hence when veneers are bonded thereon by hot pressing some melting of glue takes place permitting "checking" at glue line. Ample time, anywhere from 24 to 48 hours, should be allowed after removal from clamp to permit moisture balance to equalize throughout in range 6 to 8 percent.

QUESTION: A plant works up pieces of 1-inch maple scrap into 6-inch widths by edge gluing electronically with urea resin. Stock moisture content averages 4 percent. This stock, after drying, is then laminated into 6-inch-thick blocks with hot animal glue, for subsequent turning into sofa feet, posts, etc. What contributes to failures in lamination assuming the hot glue has been mixed and applied correctly?

R. TUTT, JR.: The moisture content of 4 percent was too low for good gluing with animal glues. The heat generated during the RF curing operation on the resin appeared to have also imparted a case hardening effect to the surfaces to be laminated. Relieving the "case" by re-moistening, then re-drying gradually to a 6 to 8 percent moisture balance enabled them to use up balance of old stock. Controlling moisture balance in range 6 to 8 percent on the subsequent operations gave good results.

QUESTION: Assume the following winter-time conditions: heat cut down in plant overnight, stock comes to glue room in morning, moisture balance averages 8 percent, but wood and room temperatures approximate 60° F. In too much of a hurry to warm stock (and room) to 75° to 80° F. What can be done to prevent hot animal glue "chilling" and "presetting" when applied, besides changing room and stock temperatures?

R. TUTT, JR.: The addition of small amounts of dry thiourea powder in range of 5 to 10 percent (sometimes less) based on dry glue in mixture lowers the gelation point of the glue solution, retarding the rate of initial "setting-up" when spread upon cold stock, so that assembly can be made and placed under pressure before glue film has been pre-set by "chilling".

QUESTION (Paul Graham): What is the scope of application of animal glue in plywood?

R. TUTT, JR.: In plywood it is a small factor, not used commercially.

QUESTION (Roy M. Carter): In a plant using animal glue in an edge gluing clamp carrier the maple, oak and yellow poplar wood joints were preheated on a make-up table which was too hot to touch. The glue was spread, immediately clamped, and the clamp carrier was enclosed for heating. During the clamp carrier revolution of about 40 minutes the temperature ranged from about 110° F. at the clamp assembly end to about 125-130° F. at the opposite end. Why were they using heat in hot summer weather and what conditions are recommended?

R. TUTT, JR.: It sounds like they were starting off on the wrong foot by trying to speed up the operation by using too much heat. Their temperatures and preheating retarded set or cure of the glue. Both the wood and the enclosure were too hot.

When wood is cold the glue joint is frequently preheated to prevent the glue from jelling or

setting before clamp pressure can be applied and thereby avoiding "chilled" joints which may be low in strength. The wood temperature should be between 70° and 90° F. preferably around 80° F. If the wood is too hot and kept hot during the clamp time the glue may be squeezed out of the joint causing starved joints and weak bonds.

The heat in the enclosed carrier is used primarily to keep the air dry and aid in drying the water from the glue in the joint. Usually temperatures 15° to 20° higher than ordinary room temperatures are sufficient. They should not exceed 120° F. or the glue will remain soft.

It's a wonder the panels didn't fall apart!

COMMENT (Carter): They did. At least many open joints were found in the plant and finished articles.

It seems to me in using animal glue many plants are trying to speed up the setting of the glue by using conditions which actually retard setting instead of developing good strong joints by using adequate setting time.

This same quest for speed causes trouble with many other glues which could be avoided by adequate time and conditions under pressure.

QUESTION (Sherman, Masonite Corp.): Does relative humidity have an effect on the glue line? If so, how do you adjust for it?

R. TUTT, JR.: If too high it will retard drying. If too low, you may get stresses in wood from excessive shrinkage. Approximately 50 percent relative humidity is ideal.

MACY: The wood should be dried to 3 percent for vegetable glues, which have a different requirement than the resins which call for a minimum of 6 percent.

POTTENGER: High relative humidity is not so difficult as low relative humidity. Low relative humidity reduces moisture so rapidly that joints will not polymerize. High relative humidity results in slower set. It is imperative to have the equilibrium moisture content around 8 percent.

SCHLEGEL: Relative humidity is a special problem. It must be studied in all plants. It is essential to glue soon after jointing.

QUESTION: From the gluing standpoint, especially with casein glues, what are your views regarding the fact that many Pennsylvania and New York State jobs specify a flush door having a 3/16 inch or 1/4 inch solid stock outer plies?

C. F. McLAGAN: The use of 3/16 inch or 1/4 inch-thick face veneer for doors is far from good practice. The old rule that the first glue line in a door should be as far away from the "elements" as possible has long since been proven incorrect. To-day many door manufacturers refuse to employ face veneer thicker than 1/16 inch, and some restrict the face veneer thickness to 1/28 inch. I recommend the replacement of the thick solid stock outer ply with a three- or five-ply panel. These remarks apply to not only casein glues but to all adhesives, and are based on actual performance, or durability, rather than gluability.

If architects in Pennsylvania and New York State would follow the above rule, I am positive there would be considerably fewer complaints on State jobs.

QUESTION: To what extent does the incorporation of preservative inhibit mold and fungus growth in casein glues?

McLAGAN: The incorporation of the proper preservative, in adequate proportion, results in a vast improvement in inhibiting mold and fungus growth. However, it should be borne in mind the incorporation of preservative in a casein glue does not result in a completely fungus-proof glue line such as is obtainable with phenolic and resorcinol resins.

QUESTION: You stated that casein glues find extensive use in the manufacture of pine solid-core doors. Are not urea resins more adaptable to high speed production of these core blanks?

McLAGAN: Pine, southern, ponderosa, white, etc. are species that require especial precautions when bonding is attempted with urea resin. These species are very readily glueable with casein glue, without observance of any special handling. In my opinion the surfacing-just-prior-to-gluing requirement when urea resin is used, coupled with the increased pressure requirement and smoothness of surface requirement out weigh the "speed" advantages in mill production.

QUESTION: In using a casein glue for edge gluing, what steps can be taken to permit a reduction of pressure period, or the required "clamp time"?

DISCUSSION

McLAGAN: The following measures increase the "speed of set" of casein glues:

(1) Mildly elevate the temperature surrounding the clamped stock (in the case of rotary clamp edge-gluing, enclose the equipment, except at the charging and discharging end, and install a steam radiator, or unit heater, at the back.

(2) Use minimum proportion of water in preparing the mix.

(3) Use up to 1/4 part alcohol in place of 1/4 to 1/2 part of the water proportion.

QUESTION (Jas. F. Hamilton): Are adhesives available that will stick plastic to wood and maintain under steam, etc.?

McLAGAN: Casein glue is not the answer. It is a problem for development. Some success has been achieved. The volume required is still too small to warrant development. Probably some work has already been done, but not on a commercial basis.

There is a good possibility the recently introduced Epoxy Resins, or modifications thereof, will solve this problem.

POTTENGER (In further answer to Hamilton): Certain plastics, particularly melamine and phenolic laminates are comparable of being bonded to wood to resist such service as steam sterilization and prolonged cooking and boiling water. This can be achieved at room or slightly elevated temperatures by the use of resorcinol formaldehyde adhesives or at high temperatures by the use of either melamine or phenolic adhesives. Some of the thermoplastic materials can be bonded satisfactorily but none of these would be able to withstand the service Mr. Hamilton requires.

ALLAN BUTLER, Bakelite Company (In further answer to Hamilton): As I understand it, the problem relates to the room temperature bonding of injection molded polystyrene parts to wood for bobbins. There is a good possibility that the C-8 type resins may prove of interest for this application, I would suggest that some experimental work be done along these lines: first prepare the polystyrene and the wooden surface to be bonded by lightly sanding the former and by applying a coat of phenolic varnish to the latter. Afte the phenolic prime coat is fully cured the catalyzed C-8 resin should be applied to both surfaces. Pressure sufficient to give intimate contact should be applied and the entire assembly be allowed to set at room temperature for a period of time. An after bake at a temperature below the softening point of polystyrene will improve the moisture resistant characteristics of the bond.

(Clarification of problem): Mr. Hamilton was asked to further define the plastics involved and the conditions of service, as both phenolic and polyester laminates have been successfully bonded to plywood with a neoprene adhesive, which bonds have successfully withstood cycling through high humidity, freezing, and 160° F. Mr. Hamilton replied that he was interested in molded plastics including polystyrene, and that the bond areas were quite small considering the stresses involved, implying that rigid high strength adhesives were required.

QUESTION: Some liquid spread adhesives are recommended to be used with a minimum assembly time. What is the reason for this requirement?

C. H. POTTENGER: It is highly important that a proper balance be maintained between the quantity of solvent in an adhesive at the time of bonding and the opportunity for this solvent to escape, either through the air or into the assembly to provide a high resin solids content in the actual glue line. If, for instance, a porous wood, such as oak assembly is undertaken while the adhesive is relatively low in viscosity, the pressure will cause excessive squeeze-out and force adhesive out of the glue line into the pore sturcture of the wood, leaving inadequate adhesive in the glue line to make a proper joint. If open assembly is provided to allow the solvent to evaporate to such a point as the adhesive viscosity is sufficiently high, the application of pressure will merely facilitate wetting by the adhesive and provide an excellent bond. We are all familiar with the dilatory effects of too high solvent content in adhesive for hot pressing. The occurrence of explosions upon opening the hot press can almost always be contributed to excessive moisture in the glue line and can be improved by better drying of the veneers, use of higher solids adhesive and open assembly prior to hot pressing.

QUESTION: What advantages do straight resorcinol adhesives have over phenol modified resorcinol adhesives?

POTTENGER: A year or two ago this would have been a relatively easy question to answer, however more recent developments in phenol-modified resorcinol adhesives have brought their performance to such a state so that they are very difficult to distinguish from the more expensive straight resorcinol materials. In general, if the phenol-to-resorcinol ratio is increased, you have increased difficulty in

bonding species such as oak and hickory at room temperature. There is also a marked tendency toward the production of poorer bondings at very low temperatures with phenol modified materials than with straight resorcinol adhesives. Where heat in excess of 110° F. can be applied for the cure, there is little to be desired in the phenol modified adhesives of today.

QUESTION: If light-colored exotic woods are to be glued on a decorative item and the highest waterproofenss is required, which adhesive should be chosen?

POTTENGER: When light-colored exotic woods are to be glued, and highest waterproofness is required, it is of course most desirable to use a melamine formaldehyde adhesive and provide the necessary heat for its cure. If moderate heat only can be applied, some of the light colored acid-curing phenolics should prove worthwhile, if the acidity is not high enough to be dangerous to the wood fiber. Some work has been done using resorcinol-formaldehyde adhesives at moderate curing temperatures 110-120°, and allowing the adhesive film to become almost tack free by open assembly prior to pressing. In any case, effective application of melamine adhesives would be most advantageous.

QUESTION: You have not mentioned boil resistance. Has this property lost significance?

POTTENGER: Boil resistance was accepted as an early criterion of durability at the time of the last war. Since that time vacuum pressure cycle test at room temperatures in which glued joints are heavily stressed. Introduction of water and forced drying at room temperatures have been adopted as a more significant criterion of durability. Obviously, wooden assemblies are seldom boiled, but are subjected to swelling and shrinking with changes in moisture throughout their useful life. Incidentally, most adhesives, if not all, which adequately pass the vacuum pressure cycle test show a high degree of boil resistance.

QUESTION (Mr. Watson): How about the harmful effect of formaldehyde fumes on workers, especially on lungs and eyes.

POTTENGER: The manufacturers do not have trouble in field. Personal cleanliness helps and venting keeps the concentration low. About 3 percent of persons are supersensitive to fumes, regardless, especially blonds and redheads. There is no cumulative effect. Dermatitis develops only in sensitive people. An immunity will develop. There is no special effect on lungs and eyes, 20 years experience has shown no disorders.

QUESTION (Jas. F. Hamilton): What is the possibility of blond resorcinol?

POTTENGER: Light-colored resorcinol resins have been made in the laboratory. The light color was achieved by the use of bleaching agents and the darkening which followed rendered the adhesive as wine red as untreated adhesives within a very few hours after the adhesive was spread. No success has been achieved in making a light, stable, blond resorcinol glue line. Interesting examples of this are the patching adhesives used on the West Coast. At the time of use they are sufficiently loaded with pigment, either titanium oxide or other oxide, and rendered them very light pink and very pleasing in color at the time of use. Exposure to sun light, however, causes them to again turn dark, so that the pleasing effect must generally be for the benefit of the plywood manufacturer and not for the user of the finished product.

QUESTION (T. D. Perry): Will edge joints in solid lumber cured in electronic machine give more trouble than animal glue cured for long time? Not level on surface.

POTTENGER: The reason for sunken joints in general is introduction of too much moisture with the glue spread causing local swelling and dressing to finish dimension while the joint area is swollen. As moisture is dissipated shrink occurs in area where excess swollen wood has been removed causing "sinks".

Remedies: 1. Use high solids glue. 2. Condition glued stock before dressing.

QUESTION (Bill Early): Why is it harder to glue 5/8 oak on an electronic machine than 4/4 poplar?

McLAGAN: Condition of the stock most likely reason, since many bond oak on RF edge-gluing machines very successfully. The edges or gluing surfaces, must be properly "jointed", or perfectly true, and the stock must be free from excessive warp and twist.

T. D. PERRY (In further answer): The thinner the stock to be glued, the more difficult to apply even pressure all over the joint. Excess pressure makes the stock buckle up at the joint.

It is always important to glue as promptly as possible after the edges (which receive the glue) are machined. A few hours is reasonable, but

several days delay may reduce the quality of the glue joint.

QUESTION (F. T. Parrish): What kind of high grade water is used to make the price differ ential between dry and wet urea?

T. D. PERRY: Glue manufacturers use a good quality of municipal water, suitable for human consumption. Urea-formaldehyde resin adhesives, as made by the chemical manufacturer, are in liquid form, requiring a metal drum for shipping. The evaporation of the solvent is an extra operation at an extra cost, but a cheaper container is adequate. These types of packaging tend to equal the cost to the consumer on a pound basis. A liquid resin, at 8 cents per pound, with 65 percent solids, should cost about 12-1/2 cents per pound as a powder. Divide the liquid cost by the percentage of solid content.

POTTENGER (In further answer): For years the manufacture of urea formaldehyde adhesives was undertaken by a relatively few research minded chemical concerns who developed these compositions to their present high state of usefullness to the woodworking industry. Rather considerable sums were expended in investigating the formulations and modifications necessary to produce a highly stable, conveniently operating urea formaldehyde adhesive of today. After the development work had been done, a great many newcomers entered the field, virtually copied the better formulations and sold and are selling on the basis of reduced price. The result is that urea formaldehyde resin manufacturers today, to meet this competition are selling so close to cost that they can no longer maintain research and development in this field. If the woodworking industry desires to see progress in resin adhesives over the next 15 years as great as the progress made over the past 15 years, it should be willing to pay a reasonable price for its bonding adhesive and should diligently question its suppliers as to the effort they are making toward improving urea formaldehyde materials for the future.

QUESTION (Mr. Nearn): What about gap filling adhesives?

POTTENGER: There are many reasons why thick glue lines are detrimental to good bond strength and durability. One of the serious factors is the fact that most of the adhesives are applied in a solvent mix. The active component polymerizing to a solid resin physically includes the residual solvent which later disappears into the wood, leaving a honey comb or hollow structure as the adhesive member. Where thin glue lines are made, the escape of the solvent into the wood is, for all practical purposes, complete at approximately the same time that the resin polymerization action is complete, leaving a strong, almost continuous resin structure in the glue line. Certain urea-formaldehyde adhesives have been formulated in which a large part of the solvent consists of a reactive material which enters into the polymerization reaction with the major resin component and does become a part of the solid resin constituent. Such adhesives have greater tolerance to thick glue lines than do the conventional urea formaldehyde adhesives, or in fact than do the resorcinol formaldehyde adhesives which show much better unmodified behavior in this respect than do most ureas. In general, adhesives modified for craze resistance can be used at a maximum glue line thickness of about .020 to .025 of an inch, whereas unmodified ureas should be used only for close work to .002 to .007 of an inch and unmodified resorcinols show satisfactory results up to approximately .012 of an inch.

QUESTION (F. N. Good): How much better is a serrated (tongue and groove) then flat, when edge gluing?

R. H. TUTT, JR.: Surface area is greater, uses more glue, you get more coverage.

SCHLAGEL: The only advantage is to line stock up. Is good for 16-foot stock in question. Disadvantage--loss of stock in cutting tongue and groove.

FLINCHBAUGH: With animal glues, which normally have gap filling qualities with no loss of strength, a serrated or tongue-and-groove joint is satisfactory.

With resin or other synthetic glues which normally do not have gapfilling qualitites and which demand wood-to-wood contact, serrated or tongue-and-groove joints are impractical and provide less strength, even though the area is increased. Production machinery makes perfect contact over entire joint area impossible leaving less wood-to-wood contact area than would be normal in a butt joint.

PERRY (Summary of comments on faulty use of glue): The most satisfactory results with any new glue will come only when the glue manufacturer and the user cooperate heartily. The glue manufacturer knows what his glue can do, and the user knows what his product requires. A failure to cooperate will mean dissatisfaction all around.

QUESTION: What accounts for the cost discrepancy between the liquid and solid ureas on a solid basis?

W. K. SCHLEGEL (Monsanto): Let us use the word differential rather than discrepancy between the cost of liquids and powdered ureas. It is well known that, in the manufacture of powdered ureas, the very expensive spray drying operation is necessary. Therefore, due to this additional manufacturing step, there will always be a cost differential between liquids and powders. Of course, in the manufacture of powdered ureas, we start originally with a liquid which is spray dried whereas in the case of preparing for sale the liquid ureas, they are virtually ready for shipment at the time they are drawn from the kettle.

QUESTION: What are the durability aspects of resin adhesives?

SCHLEGEL: The durability aspect of resin adhesives is such a wide subject to be covered in an answer of this sort that it would be my suggestion to procure the Forest Laboratory Bulletin No. 1530 which is a summary of the durability of all of the commercially available adhesives. This question is far too comprehensive to answer in a relatively short space.

QUESTION: What are the relative merits of liquid urea resins vs. powders?

SCHLEGEL: The relative merits of liquids versus powders is a rather intangible question, so let us consider several of the most important factors which determine the properties of this type of adhesive.

In the case of liquids, we have a stability approximately 1/4 of that of powders so it would give the powders a decided edge from the standpoint of storage stability. Costwise, the liquids have a decided edge due to the lower conversion cost in the manufacture of this type of resin. Thus we have a cost advantage of liquids as compared with powders.

We have a matter of convenience to be considered. In the case of powders relatively small spaces are required to store a given amount of powdered resin as compared to liquids while, on the other hand, in the case of liquids, we do have the opportunity of storing in tanks whereby considerable floor space is saved and considerable labor is saved due to the fact that the material can be pumped from this place to where it is used in the plant.

Both powders and liquids are frequently supplied without having catalyst incorporated. However, there is an advantage to the powders in that we are able to incorporate catalysts and fillers whereby the powder is ready for use when mixed with appropriate quantities of water. It is impossible to precatalyze liquids.

Quality Timber Supplies in the Northeast[1]

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Two factors impel us to examine the supply of quality timber available to the forest-products industries, particularly those industries that depend on lumber.

First, the cost of raw materials, in the long run, has tended to become an increasing part of the total cost of the finished product. One of the reasons for this is that technical progress has been more rapid in manufacturing than in the production of primary forest raw materials.

Second, and more important perhaps, are the diminishing supplies of high-quality saw timber on accessible sites.

Both of these factors are difficult to evaluate on a regional basis because the Northeastern forest-products industry is not an isolated industry. Its technology and resources are by no means limited to this section of the country. However, even though we recognize no particular merit in regional self-sufficiency as such, it is important that we keep abreast of the estimates of the amounts and quality of timber resources close at home. Information on these subjects is limited, but we should be able to draw some good general conclusions regarding the quality timber supply in the Northeast as a whole.

IMPORTS VS. EXPORTS

Before you get very far with a study of the timber-supply situation in the Northeast you notice an apparent conflict. On the one hand, published estimates show that (lumping all species together) we still have a rather sizeable volume of standing timber. On the other hand, you learn that we import more lumber than we produce in the Northeast; that some firms see the end of their local supplies of stumpage and that other firms are hauling logs over distances that you never would have thought possible 10 years ago.

For example, let's take a look at this matter of lumber imports from other regions. Lumber production in the Northeast in recent years has been less than 3 billion board feet per year, about 7 percent of national lumber production. Our annual requirements for lumber in manufacturing alone exceed 2-1/2 billion board feet. When you consider our even greater requirements for lumber in construction and other uses, you see that we fall far short of producing even half of the lumber we use[2].

In 1950, carload rail shipments of lumber to the Northeast exceeded 6 million tons; shipments originated here were a little more than 1 million tons[3]. Assuming that a thousand feet of lumber weighs 1-1/2 tons, total receipts of lumber exceeded 4 billion board feet and shipments were about 3/4 billion board feet. No doubt some of these rail movements were within the region. But it seems likely that, if water and truck transfers were added imports of lumber would exceed exports by more than 4 billion board feet per year.

PLENTY OF FORESTS, BUT--

In addition to lumber, I am sure you can think of many other forest materials for which we are wholly or partly dependent on outside sources. The historian would say that this is just the situation you might expect in a region that has been long settled and has made heavy inroads on its forest resources for many years. The forest-products industry in the Northeast has always been a sizeable one. In terms of either number of establishments, production workers employed, or value added by manufacturing, more than one-fourth of the entire forest-products industry (lumber, furniture, and paper combined) is located here. This is as it should be, for, with nearly 30 percent of the country's population, we also have a sizeable

[1] Presented at meeting of Forest Products Research Society, Northeast Section, York, Pennsylvania, May 22 and 23, 1952.

[2] Merrick, Gordon D. 1951. Wood used in manufacture - 1948. U. S. Dept. Agr. Forest Resource Report No. 2, Washington.

[3] Interstate Commerce Commission. 1951. Tons of revenue freight originated and terminated in carloads by groups of commodities and by geographic areas--Class I steam railways. Statement No. Q-550 (SCS), calendar year 1950. Washington.

share of the national market close to our manufacturing plants.

The available statistics show that 3 out of 5 acres of land in the Northeast support forest growth[4]. Every one of our Northeastern states is more than one-third forested. And every state except New York, New Jersey, Delaware, and Maryland has more than half of its land in forest production. Nearly 16 percent of all the commercial forest land in the Nation is right here in the Northeast. Yet we cannot get even half enough local wood to keep our industries going. Why?

Quality, or the lack of it, is the answer.

QUALITY IS THE RUB

When you think of quality timber supplies you think of the bigger trees, since size is one of the most important criteria of tree quality. Some 85 percent of the forest land in the Northeast carries small trees or stands so light they contain less than 5,000 board feet per acre. Over 50 percent of the forest land carries less than 2,000 board feet per acre. Much of this small timber can be logged economically for bulk products such as pulpwood, mine props, or low-grade logs; but it is not likely to yield much saw-log material of good quality now. Properly managed it may grow to good quality in the future.

Thus for quality timber we can look to only one-sixth of our commercial forest area or something less than 10 million acres. On these acres we have about 60 billion board feet, a little less than half of all the saw timber in the Northeast. As yet, unfortunately, we have no good estimates of the amount of this timber that is of high quality. However, considering only some of the elements of quality we can break this volume down a little farther.

Of the 60 billion board feet in our best saw-timber stands, one-third is softwood and two-thirds are hardwood.

There is not much to say about Northeastern supplies of quality softwood except that they are very low. Select grades of white pine lumber, for example, constitute less than 3 percent of the total regional cut. Studies of white pine lumber yields, made about 15 years ago in New England, showed even then that 75 percent of the volume cut was in No. 3 Common or poorer grades. We may have a small volume of high-quality spruce left in the Northeast but, under present ownership conditions, little of it can be expected to reach the lumber market.

THE HARDWOOD SUPPLY

The hardwood situation is somewhat better. Hardwood resources have not been exploited as intensively as softwood. We still have some areas where the hardwoods have never been cut simply because there is, as yet, no way of transporting logs that will not float. Although the Northeast has less than 8 percent of the Nation's total saw timber, we do have nearly one-fourth of all the hardwood saw-timber. Hardwood saw-timber volume exceeds softwood saw-timber volume in every one of the Northeastern states except Maine and New Hampshire.

By drawing on both published and unpublished results of the Forest Survey of the Northeast it is possible to make a rough estimate of the quality of hardwood timber in the Northeast. The criteria of quality are those developed by the Forest Products Laboratory for grading hardwood logs in terms of their suitability for standard graded lumber[5]. In general, it appears that the 40 billion board feet of hardwood saw-timber with which we are concerned is of the following quality:

1. About 20 percent, or 8 billion board feet, is in relatively clear logs that would yield some two-thirds of their volume in the higher grades (No. 1 Common or Better) of standard lumber.

2. About 25 percent, or 10 billion board feet, is in logs that have a considerable number of knots and other defects. Less than one-half of the lumber yield would be in the higher grades.

3. The remainder, 55 percent or 22 billion board feet, is in logs that have numerous knots and indications of other defects, including small diameter. Less than one-fifth of the lumber yield of these logs would be in the higher grades. This volume also includes logs that, while not suitable for standard lumber, would make commercial construction items and ties.

[4] U. S. Forest Service, 1950. Basic Forest statistics for the United States as of January 1945. Rev. to Sept. 1950. Washington.

[5] U. S. Forest Products Laboratory, 1949. Hardwood log grades for standard lumber. Proposals and results. U. S. Forest Products Lab. Rpt. D1737. 15 pp. Madison, Wis.

Thus, our better hardwood timber stands, if cut into standard lumber, would probably yield less than 13 billion board feet of the upper grades of lumber--about one-third of the total volume in these stands. But only some 9 billion board feet of uppers are found in the higher-grade logs that are normally profitable to operate.

UTILIZATION PROBLEMS

These rough estimates may have some meaning for firms that use hardwoods of all species. Hardwood sawmills do, of course, saw some of the lower-grade logs, but their margin of profit depends on the supply of the better grades. If your specifications are also limited to certain species--if you cannot use beech, for instance--this estimate would be lower. Or if you are interested only in high-grade veneer logs, the supply of standing timber of species and quality suitable for your needs may be quite small.

Another alarming aspect of the situation is that not all of our high-quality timber goes for high-quality uses. Much of the good timber goes into pulpwood, mineprops, and even fuelwood. Offsetting this is a gradual movement toward best use, which should help the situation. For example, some of the pulp mills seem to be considering the possibility of diverting their better logs and bolts to higher uses, and some of the sawmills divert suitable logs to veneer instead of sawing them into lumber.

In spite of the heavy drain on the limited quality elements in our hardwood forests, we are not cutting as much hardwood timber as we grow in the Northeast. This situation looks good on the surface, but most of the growth is being put on the poorer trees, many of them of sprout origin. If we consider the forest as a crop and cut only the annual growth, we probably have less than 1-1/2 billion board feet of growth in the better hardwood stands. Of this about one-third, or 1/2 billion, is in uppers. Yet our manufacturers use about 1-1/3 billion board feet of hardwood annually, most of which is uppers.

HOW LONG WILL IT LAST?

Given the quality hardwood volume that I have described, how long will it last? It may be possible for an individual plant operator to answer this question for his own area, but a realistic answer for the Northeast as a whole cannot be given. Much of the timber will never get to the open market; the trees are growing; we are now importing some hardwood materials from other regions; and the demand for hardwood--like supply--is not static. These are all reasons why any forecast is difficult to make or defend.

But we do know: That the volume of good-quality hardwood now in the woods is not all available for high-grade use. That, proportionately, low-grade timber supplies are increasing. And that industrial demands--on the increase volume-wise--have not let up with respect to uppers.

To cope with this unfavorable situation the hardwood-using industry may lower specifications and import more hardwood from other regions. These two alternatives cannot be relied upon in the long run because they tend to increase costs and thus upset the competitive position of the industry with respect to substitutes and to other regions. Furthermore, there is evidence that the quality situation in other regions has also deteriorated so that industries there may also be looking elsewhere for wood.

In the long run another alternative seems to offer the best opportunities. This is to promote the conservation and growth of the existing forests so as to grow quality timber. Commercial forestry is profitable now and it will become more profitable as the supply of timber gets tighter and as stumpage prices rise. And it is essential to protect present investments in the wood-using industry.

NOW OR LATER?

It is true that this latter alternative involves certain difficulties that must be recognized: (1) The scale of operations of much of our Northeastern hardwood industry is rather small; so vertical integration of land holdings and manufacturing plants may be difficult to arrange. (2) Long-run investments in forest land may appear less attractive than other investments. However, this situation is changing as more investors recognize the capital-gain features of forest ownership. (3) A longer time is required to grow timber for high-quality uses than for less demanding uses. During this time the independent forest owner is continually balancing the price he can get for his small trees now against the price he might get in the future if he leaves them to grow in size and quality. Thus far in the Northeast, most small forest owners have decided not to wait.

It is sometimes said that only the Government can afford to grow high-quality timber because of the time it takes. I do not think this is necessarily true. Government-owned lands are generally the poorest and the least accessible. On the good sites in good locations I am sure that private enterprise can insure the greater part of its quality supplies if it will begin now to grow them--using the forest technology available with the same foresight it uses in applying technical improvements to manufacturing.

Coated Abrasives - New Developments[1]

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INTRODUCTION

The word "coated abrasive" is a relatively new term to the old-time wood worker who still orders sandpaper for use in his machine sanding room, his cabinet or assembly department, and his finishing room.

This of course is quite normal since Mr. Old-Timer is not familiar with the experimental work on bonding agents, grain, backings, and coating methods which is the daily routine of the technical division of the coated abrasive industry.

This experimental work, although little publicized, has resulted in the building of a technical tool that is used in almost every industry in the world today regardless of what they manufacture, whether it be products made of wood, metal, leathers, plastics, rubber, glass, and yes, even clothing.

This paper is being presented in an attempt to review the more outstanding developments in coated abrasives as manufactured for use in the woodworking industry.

THE OPENKOTE PRINCIPLE OF COATING

One of the first major changes in the manufacture of coated abrasives or sandpaper, if you prefer, was the application of the "openkote" principle of coating grain on paper, cloth or combined paper and cloth or fiber. This change was important as the "openkote" principle makes it possible to control the distribution of the abrasive grains on the backing.

This sounds relatively unimportant until consideration is given to the fact that an efficient piece of sandpaper remains a good cutting tool only as long as the grain is exposed to the work for the purpose of sanding.

The principle of the "openkote" method of manufacturing abrasive material is to provide the space between grains required as chip clearance for the accumulation of the normal residue or waste caused by sanding, thus leaving the grain exposed and free for further cutting. The importance of such chip clearance is readily apparent to the average workman sanding filler, paints, varnish, etc., either by hand or with the more modern and productive reciprocating types of sanders in use today. His coated abrasive continues to cut in a normal manner as the waste accumulates between the grains in the spaces purposely provided by the "openkote" principle of coating.

The "closekote" method of coating produces a more closely packed abrasive surface as required on jobs where pressure and stock removal are factors, such as drum sanding and flat belt sanding. On the majority of such operations, the material being sanded is dry and chip clearance is not a major factor as the pressure used causes each individual grain to act as a cutting tool, which shears off dry particles that fail to load the coated abrasive and are drawn off in the dust suction system.

When soft gummy woods or similar substances are sanded on such equipment "openkote" coated abrasives are available for use.

DEVELOPMENT OF PAPER STOCK BACKING

Sanding costs in furniture plants have been considerably reduced by the substitution of paper-backed coated abrasives for the more expensive cloth back type formerly used.

This substitution has been made possible by the constant research and development work of the coated abrasive industry to produce a cylinder-stock paper with sufficient tensile strength for the intended sanding operation.

The average drum sander or flat belt sander utilizes rope cylinder paper most advantageously and with considerable economy in the furniture factory of today. Research work on paper development has included not only the strengthening of the paper, but also the perfection of the surface for coating and the introduction of means for producing abrasive papers that lie flat when in use without the tendency to curl, peel, or crack.

IMPROVEMENTS IN CLOTH BACKINGS

The several types of cloth used in the manufacture of coated abrasives have undergone many changes in recent years, both as to the con-

[1]Presented at meeting of Forest Products Research Society, Northeast Section, York, Pennsylvania, May 22 and 23, 1952.

struction and the processing prior to coating. These materials, generally known as drills, jeans, finishing cloth and sheeting are all purchased as grey goods and require finishing to technical specifications, before they can be used in the manufacture of coated abrasives.

These finishing operations consist. in general, of bleaching, shrinking, dyeing and filling both the front and the back side of the cloth all to pre-determined technical specifications. All materials are straightened to a point where the threads are even and parallel in a tentering machine especially designed for this operation. These even and parallel threads are a necessity if the cloth backed coated abrasive is to be torn evenly into belts of various widths as in the case of moulding cloth.

The introduction of more efficient mechanical moulding sanders accelerated the development of abrasive cloths with the proper flexibility, as required to sand the different contours of mouldings. Considerable research work has been done on this aspect of coated abrasives, resulting in the availability of material that is unflexed, as used on disc sanders, single-flexed for belt sanding of flat work, and double and triple flexed as required to belt sand the intricate shapes and contours of the modern furniture of today.

All flexing operations are of a technical nature and require considerable "know how" as overflexing is generally detrimental to the productive capabilities of any piece of coated abrasive.

GRAIN IMPROVEMENTS - HEAT TREATING - GRADING - STRUCTURE

The garnet grain used in the manufacture of coated abrasives is the same lovely mineral of exquisite jewelry. In its natural state as mined in the Adirondack Mountains, it is red in color and ideally suited to the manufacture of sandpaper because of its inherent sharpness and normal type of elongated fracture under pressure. It is, however, necessary to improve the ruggedness of garnet grain to prevent the mineral breaking down prematurely when used as an abrasive. This is done by a heat treating process whereby the mineral s toughness or temper is improved to a great degree with a resultant increase in the productive life of a garnet coated abrasive at higher machine speeds than were previously possible with unprocessed garnet grain.

The artificial minerals, aluminum oxide and silicon carbide, man made in electric furnaces for use as abrading agents have been constantly improved since they became available in commercial quantities during the early part of the 20th Century. Industry has benefited enormously by these improvements which have included not only the strengthening of these grains but also the control of their structure as to shape and type of fracture. In the woodworking field, aluminum oxide grain with its rugged, chunky structure is ideally suited to the average woodworking sanding operation especially when hard woods are being sanded on high speed equipment. This artificial mineral is coated on cloth, paper in various weights, combined cloth and paper and on straight fiber. In all cases, the type of grain fracture selected is in consideration of the sanding operation to be performed.

During recent years, the grading of all minerals used by the abrasive industry has been constantly studied. The importance of close particle tolerance has been recognized as essential to modern finish requirements, and coated abrasives are now manufactured to extremely close tolerances.

COATING BY THE ELECTROSTATIC METHOD

The greatest single improvement in the manufacture of coated abrasives during the past several years would appear to be the perfection of the electrostatic method of coating the grain on the backing. By this patented process, it is possible to control the position of each abrasive grain, together with the orientation or distribution of the entire mass of grain making up the surface of the coated abrasive item.

The process governing the electrostatic method of coating is relatively simple. It consists briefly of passing the abrasive particles between two highly charged electrodes of opposite electrical force. As the grain enters the field of electricity, it is charged by the nearest force which causes it to be immediately attracted to the opposite pole. The lines of electrical force between the two electrodes cause the particle to rise lengthwise and become imbedded in the adhesive coated backing which is also being passed between the electrodes.

This controlled method of coating makes it possible, to produce coated abrasive surfaces of such uniform dimensions, as are required to produce finishes measured by the millionth part of one inch.

IMPROVED BONDING AGENTS

For many years the only accepted adhesive in the coated abrasive industry was high grade animal glue which contained the necessary bond-

ing quality and the proper degree of flexibility, as required for use in manufacturing coated abrasives.

Heat, as generated on most sanding operation, has always been detrimental to the productivity of "glue bond" abrasives. The coated abrasive industry's constant search for suitable bonding materials, that would remain unaffected by heat, has been successful and today coated abrasives are manufactured with several types of adhesives in addition to animal glue.

The first of these new types was "Durabonded" a patented process whereby the adhesive is made much harder and more heat resistant. This is accomplished by dispersing minute particles of inert, infusible, non-absorbent material of carefully controlled shapes and sizes throughout the adhesive itself.

Meanwhile, experiments proved the feasibility of using certain types of resins as adhesives, because they held all the necessary qualities required, namely bonding strength, resistance to heat, and flexibility. Today, "Durabonded", resin, and combination glue-and-resin bond abrasives are available with productive qualities that continue to amaze both the manufacturer and the user. They are the ideal cutting tool for use on the high speed sanding equipment being built by machine manufacturers for increased production.

"NO-FIL" FINISHING PAPERS

The most recent development for the furniture and allied industries is a non-loading finishing paper. Designed particularly for use on a high solids clear sealer, it has vastly improved the quality of finishes wherever used - probably the only development in the finishing line that was a direct cooperative effort between a producer of finishing materials and a coated abrasive manufacturer. Heretofore the production of a clear, hard, mar-resistant sealer with high solids content was non-existent because quantity was not attainable at a reasonable cost. The development of the non-loading paper for sealer sanding has made quality finishes possible on a production basis.

The use of conventional sanding sealers has long been a source of headaches in the finishing system but has been tolerated because of the inability to sand economically and quickly a clear high solids sealer. Introduction of the non-loading finishing paper, in both garnet and silicon carbide grains, has made possible the production of a better finish at no loss of quantity of finished product. Only by the use of this treated paper can these better sealers be used successfully. Efforts to sand such sealers with the conventional type finishing papers generally result in failure due to excessive loading by the abraded particles of finishing material. By aid of the special ingredients used in the non-loading papers this type of trouble is eliminated, making possible for the first time the use of these high solids, clear sealers.

Here truly, is a definite forward step in the finishing process for the woodworking industry. The coated abrasive industry is proud to have had a part in this new finishing technique through the building of an entirely new product and similar new products will be made as required.

High Pressure Laminates[1]

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INTRODUCTION

This paper is concerned with the type of high-pressure plastic laminate that is generally referred to as decorative material. This name is perhaps somewhat misleading; certainly the materials, as a class, are very decorative, but, in addition, they are very utilitarian. They are outstanding in the quality of maintaining beauty over long periods under conditions of not only extremely hard wear but also considerable abuse.

Historically speaking, decorative laminates have been made for a great number of years. The first production in any quantity was in the 20's. Phenolic resins were used throughout in materials of that day. The use of the inherently dark-colored phenolic resin restricted the color range somewhat, and the bright colors of the present-day materials were impossible to obtain. Nevertheless, some very pleasing patterns were obtained, particularly in the line of wood grains. These phenolic laminates enjoyed considerable popularity.

In later years, urea resins were used on the surface of the laminates to obtain better colors. However, the ureas were soon supplanted by the melamine resins, and within a fairly short period both the phenolics and ureas fell into general disuse as surfacing resins. In present-day laminates, melamine resin is generally considered the standard for use on the surface of the material.

MODERN LAMINATES

The construction of present-day decorative plastic laminates is fairly well standardized among the better manufacturers, although, quite naturally, differences of opinion exist. There are, of necessity, variations in the constructions used to obtain the various colors and patterns. All laminates of the type under consideration herein are made by impregnating paper (or cloth or thin wood veneers) with a solution of a thermosetting resin. The impregnated material is dried by a continuous process to a point where the resin is in the early stages of cure (the so-called "B" stage). The sheets are then cut to sizes and laid up in the desired combination. These stacks are then placed between polished press plates and consolidated under heat and high pressure in a hydraulic press.

The most popular type of decorative laminate today is the so-called printed pattern. This type is made in a wide variation of basic patterns and colors. Manufacturers are continually striving to develop newer and more pleasing designs. The older patterns of linen and other cloth-weaves still enjoy considerable popularity, but, of late, a number of other very interesting and decorative patterns have been evolved. In particular, the development of a simulted three-dimensional effect has opened up a new field for the artists and designers. The shading and coloring of these designs give the very striking effect of a rough, contoured surface while retaining, in actuality, a very smooth and polished surface. This type of design is becoming increasingly popular.

COMPONENT MATERIALS

The core material contributes the major portion of the strength of the laminate; therefore, a high-strength base, usually a sulfate kraft paper, is used. The resin used in the core is phenolic, and the resin content is held to a relatively low figure (usually in the range of 35 to 40 percent). This proportion of resin to paper is adjusted so as to provide sufficient resin to protect the fibers adequately from moisture penetration on the one hand, while, on the other hand, it must be sufficiently low in order that good mechanical strength is obtained. A sufficient number of plies are laid up to provide the required thickness of core, and over this buildup of core sheets is laid the printed pattern or design sheet. The base fiber of this sheet is a refined pulp, such as alpha cellulose or rag stock. It is usually pigmented by the paper manufacturer to the base color of the design or pattern desired. On this base color stock is printed the design or pattern. This sheet is then impregnated with a melamine resin to a medium resin content.

Far from the least in importance in the build-up of the laminate is the overlay sheet. The base paper in this case is a fairly thin, unpigmented sheet of a very high grade of paper, usually alpha or rayon stock. This paper must

[1] Presented at meeting of the Forest Products Research Society, Northeast Section, York, Pennsylvania, May 22, and 23, 1952.

be very absorbent, It is impregnated with a melamine resin, and in this case a high degree of resin saturation is essential, as the sheet, when finally compressed in the pressing operation, should become translucent almost to the point of being transparent. The function of the overlay sheet is to provide a hard, good wearing surface, as its presence protects the design or the pattern from being worn away. This overlay sheet must be carefully processed so that, even after the finished laminate has been subjected to considerable wear, it will still maintain a good surface finish.

The selection of the printing inks used in the pattern sheet is especially important, as they must not only be light-fast but also heat-stable at the temperatures of the subsequent processing. This printing is commonly done by the direct process. Either single or multiple color printing is used, depending on the particular decorative effect that may be desired.

The preparation of the printed rolls for this work is both an art and a science in itself. Most designs are based originally upon photographs of naturally occurring designs or patterns. In the case of a wood grain, for instance, the object is to reproduce the original with the greatest possible fidelity. However, in the case of some of the other textured effects the photographer, the artist, and the photo engraver will call upon all of the tricks of the trade that are at their disposal with the result that the final design may bear little resemblance to the original object photographed.

The solid colors are made without the use of an overlay sheet. In such cases, however, both the absorbency of the base paper and the impregnating process must be carefully controlled so as to yield a very thorouth impregnation of the resin. This, in turn, gives a substantially thick, uniformly wearing surface, which maintains its beauty under hard service.

In examining these constructions, it will be noted that full recognition has been given to the fact that these materials will be used in applications where they are subjected to extremely hard wear. The products are designed to be as wear-resistant as possible. Equally important is the fact that they are designed to maintain their beauty and brilliance even after the surface is partially worn away.

PERFORMANCE REQUIREMENTS

The performance requirements of decorative laminates have long been recognized throughout the industry. As would be expected, the recognition of performance requirements was the forerunner of the establishment of product specifications and standards. This is a reality in the case of decorative laminates. At present there is a standard which has been established and published by the National Electrical Manufacturers Association under the designation of "Laminated Thermosetting Decorative Sheets," (latest revision - June 1951). This standard covers not only such matters as standards for sheet size and thickness, tolerances on thickness, etc., but also outlines the proper methods of testing the physical properties of the material. Further, it sets up the minimum requirements on the results of the various physical tests. In this respect, it very definitely establishes a minimum standard of quality for the product. It covers recommended practices for both the fabrication and the application of the material. A brief resume of the minimum requirements of the NEMA Standard is given in Figure 1.

Although all of the properties covered in this standard have a definite significance in relation to the quality of the finished laminates, certain of the test methods used are particularly interesting and, therefore, are worthy of discussion.

The method of testing for resistance of surface to wear, commonly called the wear test, is made by subjecting the material to a fast-cutting abrasive under carefully controlled conditions. This test utilizes a modification of the standard Taber Abrasor, the wheels of which are surfaced with a relatively fast-cutting sandpaper (see Figure 2). Provision is made for standardization of the abrasive used by measuring the cutting action on a standard zinc plate.

In evaluating the wearing qualities of a surfacing material, we are concerned with the evaluation of three important factors. It will be seen that this test gives a quick and reliable evaluation of all three of these factors, which are:

1. The rate of wear - this is inversely proportional to the actual resistance to wear of the material. It is measured quantitatively by measuring the weight loss of the test specimen during the course of the abrasion test.

2. The total amount of wear that can take place before the piece is considered as "worn out". This is also measured quantitatively by checking the number of cycles required to obliterate the pattern or to change the color or the texture of the piece.

3. The appearance of the material during that period when wear has taken place but prior to the time when it is considered worn out. This is determined by visual examination.

The standard also includes a quite simple and reliable test for resistance to boiling water. Such resistance is certainly a prime requisite of any material which would be used on kitchen work surfaces.

High-pressure laminates, however, are expected to withstand more severe conditions than boiling water and, therefore, included in the standard is a test which involves the material in exposure to hot wax. This test, which is known as the "Method of Test for Resistance of Surface to High Temperature," is intended to measure the ability of the material to withstand normal kitchen abuse, such as spillage of hot grease and the like. The temperature involved in this test is 180° C.

When materials are used for table tops, it is of primary importance that they be able to withstand the effects of burning cigarettes. Accordingly, a test for this characteristic is included in the standard. The conditions occurring during the burning of an actual cigarette are far too variable to be depended upon as a fool-proof reproducible test method. Because of this, it was necessary to do a considerable amount of research before developing this particular test. In the course of this work, it was determined that the major effect of a burning cigarette when placed upon a table top is one of radiant heat. Recognition of this fact suggested the use of a small localized radiant heater as a suitable testing apparatus. This test fixture is illustrated in Figure 3. Interestingly enough, this apparatus evolved from the original use of a standard automobile cigarette lighter. The procedure of standardization of this test is rather involved, as it is necessary to go further than merely to control the electrical circuit but also to standardize the equipment by actual measurement of the radiant heat given off by the heater. Once the equipment is standardized, however, the actual testing is quite simple and very reproducible. It has been definitely established that materials that pass this test as being cigarette-proof will not be damaged by cigarettes in actual service.

Resistance to staining is very important, particularly in applications throughout the home. Therefore, a very complete coverage of the various materials in use around the household has been given in the "Resistance to Staining" test.

The other test methods cover color fastness, resistance to moisture, dimensional change, and strength. As these characteristics have been fairly well covered in allied fields, no attempt will be made here to review them in detail.

HOW AND WHERE USED

Decorative plastic laminates are commonly supplied with the finish on one side only, the back side having a sanded finish to provide a gluing surface for bonding to other materials, usually plywood. The most commonly used thickness is 1/16 inch. Manufacturers' standard sheet sizes cover a wide range, up to 4 feet by 10 feet.

Fabricaton of the material is done by high-speed cutting equipment of the type that is generally available in woodworking establishments. A few modifications have to be made from the woodworking techniques. Most important is the use of carbide-tipped tools for high quality fabrication, combined with high production. High-pressure laminates, although containing no abrasives, do tend to dull high-speed steel cutting edges rather quickly.

When 1/16 inch-thick decorative laminates are used, they are commonly bonded to wood by gluing. For applications where little or no moisture is encountered, the casein and urea-type glues are entirely satisfactory. Where severe moisture conditions are encountered, resorcinol or phenolic-type glues are recommended.

In recent years, these laminates have become practically standard for commercial use in counter tops, bar tops, restaurant table tops, and the like. There is an increasing realization that the same characteristics of durability are very desirable in the home. The material has for some time been extensively used as kitchen work surfaces, dinette table tops, bathroom surfaces, both horizontal and vertical. More recently it has been recognized that the beauty and permanence of the material are very desirable in many other places in the home, and, accordingly there is a rapidly expanding use of the material for the surfaces of many items of household furniture.

Natural wood requires laborious and costly operations of finishing. When properly finished, good wood is beautiful indeed, as we can all attest. Wood finishes, however, are by no means permanent, nor will they withstand abuse like a plastic laminate. What could be more logical, therefore, than the use of decorative laminates for all furniture surfaces that

are subjected to wear or abuse? It is particularly suitable for the tops of coffee and occasional tables, dressers, and the like.

Many different patterns and colors can be, and are, used on furniture. The most popular, however, is the wood grain finish. The modern plastic wood grain is a faithful reproduction of a carefully selected and beautiful piece of wood. Moreover, it is now being supplied in a "hand-rubbed" finish, which is identical in texture to the finest hand-rubbed wood.

The plastic can be applied to the surface in the same manner as a wood veneer except that in the case of the laminated surface, no further finishing is required. From the standpoint of economy of manufacture, the elimination of the finishing operation will go a long way toward paying for the cost of the laminated surface. The manufacturer can, therefore, obtain a tremendous improvement in quality with very little increase in cost.

In the case of television cabinets, the decorative laminate can be applied very conveniently to the sides as well as to the top, thereby almost entirely eliminating the finishing operation. On console cabinets, the use of plywood backing is recommended; on the table models, howe ver, the laminate can be used without backing by adopting a somewhat thicker sheet. In either case, the economics are very favorable toward the use of the decorative laminates.

A fairly recent and very important develoopement is the use of the material in unsupported wall paneling. Earlier methods of applying material for wall paneling involved the gluing of the 1/16 inch thick laminate to plywood with subsequent application of the assembled panels to the wall. Using the newer technique, the material is supplied in a thickness of 5/32 inch and manufactured with the face side slightly concave. It can be applied directly to the wall studding. The fastening is done at the edges of the panel only, utilizing an especially designed fastening strip. Snap-on moldings having the same finish as the decorative sheet are supplied. These snap-on moldings completely cover the joints. Studs are normally placed on 16-inch centers. This method of installation has proved entirely satisfactory on sheets up to 48-inches wide. This type of application is particularly advantageous in new construction, as the elimination of plaster, plywood, or any other type of backing results in a very favorable economy of installation. (The matched snap-on moldings are illustrated by Figure 4.)

Figure 5 shows the use of the material with one piece cove and cap moldings. Figure 6 illustrates this type of installation as applied to a wainscoting section. It will be noted that in this type of construction, the panels are, in effect, "floated" rather than being rigidly held. This construction serves to allow for settling and misalinement of the structure without distorting the paneling. It also has the advantage of eliminating the need for drilling holes in the material for fastening.

Great progress has been made in this field of high-pressure plastic laminates. A number of applications have been pointed out herein; however, this article was not intended to be all-inclusive with respect to applications and certainly as time goes on, it can be expected that new techniques will be developed and the application of the material will be greatly expanded.

Figure 1

ABBREVIATED TABLE OF MINIMUM REQUIREMENTS

NEMA STANDARDS

FOR

LAMINATED THERMOSETTING DECORATIVE SHEETS (JUNE, 1951)

Wearing rate maximum - 0.08 grams/100 cycles, all classes.

Total, minimum - 400 cycles - class 1

200 cycles - class 2

Boiling water - No discernible effects.

High temperature - 180° C. - No discernible effect.

Cigarette test - minimum - 110 seconds - standard grade

10 minutes - cigarette-proof

Staining test - Must withstand 16 hours' exposure, either wet or dry, to the common household reagents, such as solvents, soaps, detergents, juices, foods, insecticides, dyes, medicine, etc.

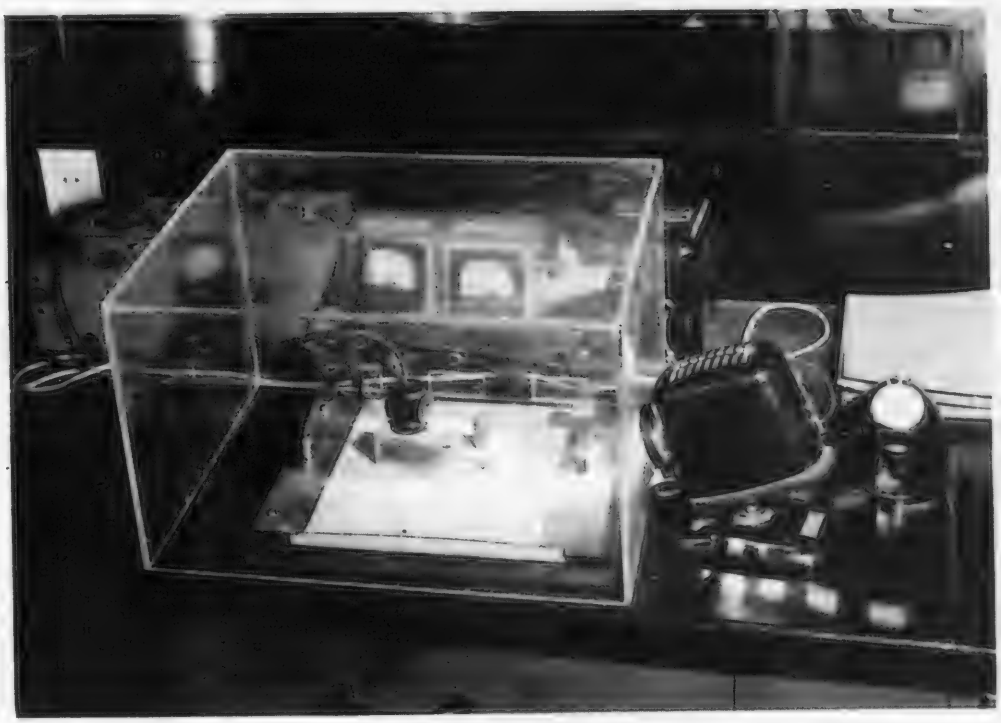
Color fastness - No more than a slight color change after 48 hours' fadometer test.

Moisture absorption, maximum - 6 percent after 2 hours' boiling.

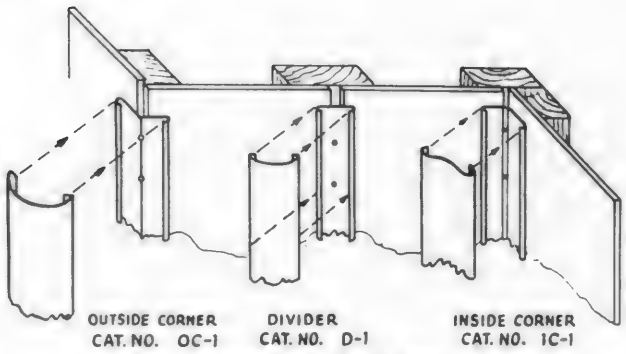
Dimensional stability - Gross dimensional change, 0.8 percent, maximum.

Flexural strength - 15,000 psi., minimum

TABER ABRASER
FIG. 2



CIGARETTE TESTER
FIG. 3



SNAP-ON MOLDINGS

FIG. 4

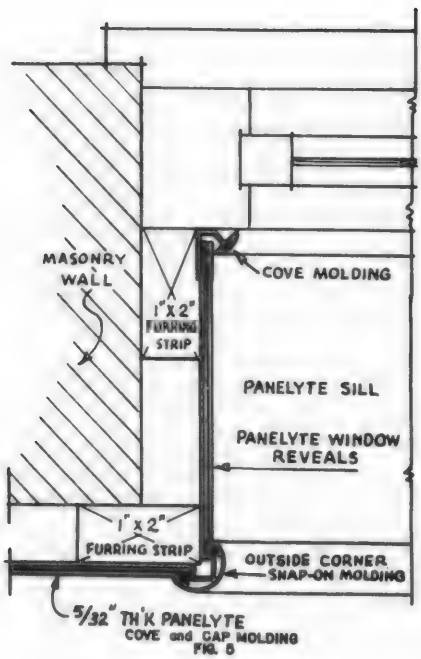
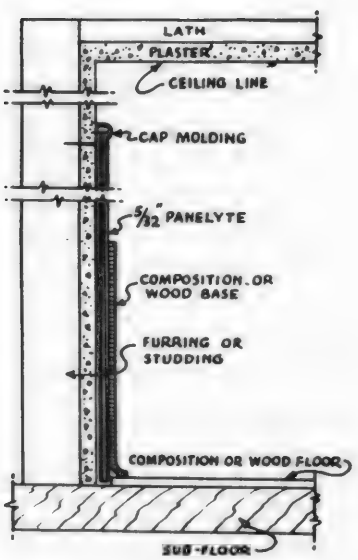


FIG. 5



WAINSCOTING SECTION

FIG. 6

A Program For Materials Conservation[1]

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INTRODUCTION

Conservation is a philosophical idea or attitude and is not, in itself, a study, science, or field of endeavor.

Conservation in national preparedness and defense is a recent development. We had none preceding and during World War I and but little before and during World War II. The engineers, with their usual resolution of everything to equation form, are calling the period we are now in, World War III minus 0.5, and no one can say at this point whether their equation is right or wrong. However, the time has come in the utilization of all of our natural resources when the concept of conservation must play a major role in the plans of those responsible for our defense, both in government and in industry.

No one knows where world affairs are headed. No one can predict at this time, to what degree it will be necessary to build up our defenses, or for how long it will be necessary to maintain them at a high level of development. Thus far, the civilian economy has not been greatly affected by mobilization for defense. However, as the program develops, more raw materials of all kinds will be needed for the manufacture of the products used in defense. In modern military activity, this means nearly every item and product used in civilian life. Shortages of certain metals and chemicals are already evident and if defense needs increase during the coming months, these shortages will become more serious and new ones will develop.

The thoughts in this paper apply to the nation as a whole and not to any one region. If there seems to be an overtone of warning, it is only because I feel strongly that we should be prepared both mentally and in our daily activities, for whatever may lie ahead.

BASIC CONSERVATION PRINCIPLES

The philosophy of conservation of materials is at present definitely a part of the mobilization program. It has to be. There is not enough of anything to support all of the uses involved as the defense program develops, without the application of conservation. This is true of our natural resources, and it is true of the raw materials and products derived from those resources.

Conservation in simple terms means proper use. It does not involve prohibition of use. The so-called conservation orders of World War II were restrictive orders and were necessary at the time. However, restrictive orders are not conservation but become necessary when conservation is lacking or when needs far exceed total supply. As long as everyone concerned sees to it that conservation is practiced, and needs and supply do not reach a critical relationship, restrictive orders will not be necessary.

As originally conceived, the conservation program of National Production Authority involved five major parts: substitution, salvage, specifications, simplification, and standardization. As far as the lumber and other wood-using industries are concerned, we must add two more - research and waste utilization.

The term substitution is perhaps an unfortunate one for it carries the connotation of the placement into use of an inferior product or material. Perhaps "interchange of material" would have been better. At any rate, it means the use of a more plentiful material or product instead of a scarcer one whenever practicable. Wood can take the place of metal now for a long list of products. In the coming months, if lumber and other wood products should in turn become scarce, the substitution of more plentiful species for scarcer ones must then be made.

Salvage means the reclaiming of materials after use and their reconditioning for reuse. During the last war, large quantities of crating, dunnage and other material were burned or thrown away. One outstanding example of salvage occurred at a large Army ordnance depot in Pennsylvania where a nail-pulling machine was designed and built which made possible the reuse of a large volume of heavy dunnage and crating material which was formerly burned to get it out of the way.

The writing of specifications for the materials and products purchased by the branches of the Federal Government bears directly on conservation, for proper specifications can assure that the agencies get the things that will meet their needs but will not involve waste or ineffi-

[1]Presented at meeting of Forest Products Research Society Northeast Section, York, Pennsylvania, May 22 and 23, 1952.

ciency on the part of the industries that make them. The permission of alternate materials for certain products when practicable is one outstanding method of accomplishing this objective.

Simplification is the reduction of complicated types and models and the elimination of "frills". Examples of the possibilities for conservation by this method can be observed in almost any industry we examine and this is needed also in the lumber and other wood-using industries.

Standardization is the adoption of certain designs, methods, sizes, etc., which will be uniform throughout a plant or an industry. This may even be carried out on an international basis, as for example, the standardization of machine screw threads between Britain and the United States, and the adoption of one rifle barrel and action in which the same ammunition can be used by both countries.

Research is always needed. The constant flow of new products and improvements in old ones coming from other industries are the results of research. Government (state and federal) and academic institutions have been carrying on research on wood for many years and a good part of the results are directly applicable in industry. The Forest Products Research Society can do a great deal to bring this knowledge to industry. There is a challenge and an opportunity here confronting the wood-using industries, to become familiar with research results already available and further to develop programs in research of both the fundamental and product development types. The nature of the wood-using industry with its large number of small producers means that industry research will have to be conducted either by the larger concerns or by combinations of smaller concerns supporting research laboratories carrying on projects of mutual benefit.

Wood waste must be reduced and the waste that is unavoidable must be fully utilized if the nation's needs are to be supplied without a severe drain on resources in the months and years ahead. We have been a wasteful nation in the past but we cannot afford it in the future.

THE FOREST

The total volume of lumber cut during 1950 was 37,951,739,000 bd. ft. This was the largest volume of lumber produced in any year since 1929, but defense requirements in the future may require still larger cuts. At the same time, the uses for pulp are increasing and the volume of pulpwood cut is increasing. In any period of national stress, heavy demands are made on the forest resources of the nation, but although the needs must be met, all possible measures should be taken to see that lasting damage is not done to the basic resource.

An outstanding example of the meeting of war needs while protecting the basic resource took place in Norway during the last war. The foresters who were able to stay at their posts saw to it that the heavy total cut necessary from commercial forests was spread as widely as possible over the entire forest area. Even in the dark days of the occupation of their country, the volume required was cut with minimum permanent damage. The total cut was controlled so well during most of the period, that after the end of the war, a forest survey indicated that, in general, the cutting during the war had actually been of benefit to the forest, and there was a larger total volume and better distribution of age classes than before the war.

This illustrates a lesson we must learn on a nationwide basis. The necessity of meeting defense needs should never be the excuse for the relaxation of technical controls over cutting. Instead, it should make clear the need for more intensive application of silvicultural methods and forest management practices, carried out through extensive technical controls over cutting.

In planning for the future, forest management should include the provision for silviculture to control the rate of growth in sawtimber stands in order to assure the strength properties desired in the products and at the same time, that the desired sizes are produced within a minimum period of years. This can be done by determining the relationship between rate of growth and physical properties for the species involved, obtaining as early crown closure as possible, and then controlling rate of growth by a thinning program.

In logging, there should be as complete an integration of operations as possible so that those logs of pulpwood size and quality will go to the pulpmill, those of sawlog size and quality to the sawmill and those of peeler log size and quality to the veneer mill. Two firms in New England, one a paper mill and the other a furniture factory, have recently worked out a very satisfactory arrangement. Instead of competing for logs, the pulp mill gets the pulp sizes, quality and species, and the furniture plant gets the larger logs for its sawmill. In the past, far too many good peeler logs have been cut into lumber and too much good sawlog material has been cut into pulpwood bolts. This represents a waste of raw material that we cannot afford.

Of the annual total of over 100 million tons or about 54.5 million cords of wood waste in the nation, about 45 percent is in the form of forest waste, or logging debris. This waste is a major economic loss and means that heavier cuts must be made to get out the required volume, some of which could be supplied by the material left in the woods. The solution of the problem of how to remove the entire content of each tree at a profit either during or immediately after the logging operation may be reached through intensive research within each forest region. This will not be easy, but it must come about if our forest resources are to stand up under future needs for forest products.

MANUFACTURING

In preparation for a long term mobilization program, all plants should put their equipment in top condition and see that all operations are conducted with maximum efficiency. Since mobilization always involves both equipment and labor shortages, this is just good business at the present time.

Wood waste produced at primary plants such as sawmills amounts to over 40 percent of the total wood waste in the United States. The volume in this type of material is far too large. It can be reduced to some extent by greater efficiency at the mills and the use of new equipment such as sash gang saws on small logs. However, there will always be wood waste in some quantity at primary plants and its utilization is a major conservation problem.

Many new uses for sawdust have been developed and advocated but thus far, the economical collection of sawdust from small mills appears to be an insurmountable problem. The same is true of slabs and edgings. We have a good deal of research results on what to do with primary plant waste but little on how to solve the problem of the assembly of the waste materials from a large number of small mills into a volume which will support a utilization plant. Until this material can be assembled at a central point at a cost which the utilization process will stand, the problem of small sawmill waste will remain with us. The debarking of sawlogs before sawing offers real promise as a means for making possible the utilization of the larger waste material for pulp and merits wider application. Considerable research is needed in this field, both on the economics involved and on new types of equipment.

The volume of wood waste at secondary plants is much less than at primary ones, but even there it can be reduced to some extent. In general, the opportunities for utilization of this material are broader, since the waste is cleaner, free of bark, and of lower moisture content than that of primary plants, but the collection problem is a stumbling block to the utilization of this material also. If the plant is large enough to produce a steady supply of sufficient volume, a small utilization process might be installed at the plant. However, when a manufacturer sets up equipment for a process to utilize the waste at his plant, he may find, if the product is successful, that he does not have sufficient waste at the plant to support the secondary product and must then either buy and transport waste to his plant or make the "waste product" from logs. Either method usually means that the product becomes impractical on the basis of cost of production. Low cost assembly of waste wood from several plants at one central point is the key to successful utilization of both primary and secondary plant waste.

PRODUCTS

As the defense program is expanded, the volume of wood products needed will increase. The needs will range all the way from round timbers to the carefully designed products such as heavy marine laminates and metal-faced plywood for special uses. Wood may be used in considerable quantity for products which have been made largely of metals or other materials in recent years. There is both an opportunity and a danger in this. There is an opportunity for the wood-using industries to regain some of the markets lost to metals and other materials but there is a danger that some of the wood products turned out may be of inferior quality and too high in price. This happened with a number of items during World War II, and after the war, the purchasers immediately switched back to the items made of other materials.

In times of national stress, the supply of metals, plastics, and other materials is not adequate to meet the total of military and civilian needs. Wood and wood products can be used again to produce some of the products that cannot be made of metal. The developments in wood technology and adhesives during recent years make possible the manufacture of products with a far greater range of characteristics than be fore and it will be possible to meet highly exacting needs under severe conditions of use. In fact, many new uses for wood and wood products are now possible due to these developments and where species, properties, treatments, and fabrication methods are properly used, wood and many critical materials are interchangeable for along list of products for both military and civilian use.

A few of the widely used items that can be made either of wood or metals are as follows:

1. Furniture
2. Truck bodies
3. Ammunition containers
4. Small bridges
5. Small boats
6. Caskets
7. Venetian blinds
8. Chests, trunks and cabinets

In the latest issue of the Basic Materials and Alternates List published by the Defense Production Administration, each industrial materials section is separated into three groups: (1) Materials in short supply, (2) Materials in approximate balance with defense and essential civilian needs, and (3) Materials in fair to good supply. Of the metals, nine non-ferrous, three precious, seven ferrous alloying elements, twenty-eight types of ferrous metal products and eighteen miscellaneous items are listed as scarce. There is a long list of scarce chemicals. If defense needs become large enough to compete with demands for civilian goods, shortages will show up in the retail markets. It must be remembered that defense needs will have first claim on all goods produced. In the Lumber and Wood Products Section of the Basic Materials List, the only items listed in the Scarce Materials Section are Port Orford cedar, cypress, Douglas-fir thick clears, ironbark, longleaf pine upper grades, softwood exterior plywood, teak and treated piling 50 feet and longer. This means that for the present at least, lumber and wood products are more readily available than many other materials.

From the early days of civilization, wood has been the material that has been used to meet many basic needs of man. In recent years however the metals, and plastics industries have made great strides through fundamental research and product development. The result has been that metals and plastics are available that areof uniform quality and properties and a host of products traditionally made of wood are now on the market made of metals, plastics and other materials. This does not mean that the new products are superior to those formerly made of wood. In fact, many items are actually inferior, but many are made to sell for lower prices and, through extensive promotion, have come to be generally accepted. This is true of both civilian and military items.

There are many items in defense that cannot be made of wood, such as tanks and fighting ships. In a full mobilization program, the supply of metals we have must be used for these items and wood used for others for which it is suited. Already, the three defense departments are recognizing this need and are taking steps to use wood in certain items where it is practicable to do so in order to relieve the drain on our non-renewable resources. We just do not have enough metals to supply both a full scale military program and civilian needs. Wood must fill the gap, and the producers of lumber and other wood products must be ready to meet the needs of an expanding program. The fact that there are adequate supplies of most wood products at the present time does not mean that this condition will continue once a full scale substitution move gets under way. During World War II, the shortage of metals was experienced first, then wood was used for many items to relieve the shortages of metals, then wood itself became one of the critical raw materials. It is for this contingency that we must be prepared, and if this situation should come about, it can be expected to continue for a far longer period than during World War II.

In conclusion then, conservation is proper use in its broadest sense. It is a necessary part of the mobilization program in both government and industry if our resources are to be able to support the heavy demands to be made upon them.

Discussion

QUESTION (Wangaard): From what you say, it appears that the high cost of wood is going to be with us for a long time. How is wood going to maintain a competitive position with regard to wood substitutes if such is the case?

McGUIRE: Among wholesale prices that go to make up the price index, the price of lumber has increased more than most other commodities over the past ten years. Barring a depression, it seems to me that these high lumber prices are going to be with us for some time to come. This means that wood will remain in a relatively unfavorable competitive position with respect to substitutes. On the other hand, wood technology is progressing at a rapid rate and I would expect that some of our losses to wood substitutes will be offset by the use of wood fiber for other materials. For the long run, the answer seems to be to insure an adequate supply of good quality stumpage so that we can keep the cost of wood in line with costs of competitive materials.

QUESTION (Hamilton): What program would economically supply the future hardwood needs of industry and at the same time would prove profitable to timber owners?

McGUIRE: Your average woodlot owner has trees of both high and low quality. He has no problem in disposing of the high-quality trees but he usually has trouble in finding markets for the low-quality material that he gets from thinnings and improvement cuttings. There is no question that on the fair and better sites these measures that remove the low-quality trees will result in a profitable operation in the long run. It is important to the industry that these poor trees be removed in order that the growth be concentrated on the good trees. Hardwood industry would help any program that seeks to increase the supply of quality material if the industry would recognize the woodlot owners' dilemma in regard to markets for poor-quality material. The industry could also help by encouraging its log suppliers to avoid "creaming" cuts. For the long run, it would be much better if the loggers themselves encouraged owners to improve their woodlots.

QUESTION (Graham): What are the major problems in growing hardwoods in the Northeast?

McGUIRE: One important problem is how to reduce losses from forest fires, insects, and disease. Another important problem is how to get better cutting practices on the land. Too many owners are inclined to make one cut per generation. More of our timber should be marked for cutting. In some areas the ownership pattern itself is a major problem.

QUESTION (Warren Bell): There seems to be much selective cutting in the South. Why aren't we doing as well in the Northeast?

McGUIRE: Selective cutting has been advocated in the Northeast for more than 50 years. Perhaps the results have not been as outstanding in the Northeast because the individual trees are slower growing than in the South. Nevertheless, I believe that under proper management we can grow as much wood per acre up here as they do down there. Taking forest products industry as a whole, perhaps there has been more interest shown in the South and more action taken than in the Northeast. However, we are making progress. The number of our farm foresters and industry foresters is growing. The recent New Hampshire Yield Tax Law is another example of the Northeast's progress toward removal of obstacles to better forestry.

QUESTION (MacLAUGHLIN): What steps could be taken by the Government to promote hardwood reforestation?

McGUIRE: Government planting programs have generally concentrated on softwoods because softwoods have been in greater demand and because softwood plantations have generally been more successful than hardwood plantations. It seems to me that we might be better off to concentrate on bringing our present stands of 10-inch trees to 20 inches as quickly as possible, rather than to expend the same effort on planting more hardwoods.

COMMENT (Caldwell): There may be considerable volumes of good quality hardwood scattered around the Northeast in small holdings. Frequently, it is not profitable to go around and buy up two or three trees at a time. Some of this high quality material does get to smaller mills where it may be poorly manufactured into low quality wood products. We could use more hardwood concentration yards in the Northeast. We would also benefit by doing more sorting of logs at the sawmill and getting small sawmill operators to recognize quality of the different kinds of material that they receive. We need more research in marketing.

COMMENT (Kraemer): Speaking of the length of time it takes to grow a good log, the highest quality softwoods are generally those that are grown the most slowly. On the other hand, the hardwoods, being porous, are of poorer quality if slow grown, and of higher

quality if fast grown. This should encourage forest owners to grow hardwoods.

COMMENT (Harry Rich): We are witnessing a greater hardwood harvest today than ever before. Many firms are increasing their cut of hardwood for pulpwood. Some of this cut is coming from stands where the softwoods were removed years ago. In mixed stands where softwoods are still present, the removal of hardwoods will result in more softwood growth.

COMMENT (Simmons): I have to disagree with Hugo's statement that hardwoods of rapid growth rate are always of better quality. For certain uses and species this is true, such as white ash for baseball bats, and sugar maple for shuttle stock, uses that require high impact strength. For other uses it is not true. Generally rapid growth in hardwoods means wood that is difficult to machine, and dimensionally more unstable than the same species of slower growth. The soft textured Appalachian hardwoods still being advertised, were of slow growth virgin timber. Fast grown second growth yellow poplar (hickory poplar) is definitely considered unsuitable for core stock because of its excessive shrinkage and expansion, and fast grown wood of other species is discriminated against for such uses as flooring and furniture manufacture that require a good degree of dimensional stability.

QUESTION (Clarke): What would be the effect of opening up Adirondack Preserve?

McGUIRE and SIMMONS: Figures on volumes of standin timber present in the Adirondack and Catskill Forest Preserves, as well as on other park areas, were not included in the paper as presented. Such volumes, if they became available for commercial use, would, of course improve the timber supply situation in the Northeast somewhat. At present, of course considerable volumes of blown-down and injured timber in the Adirondack Preserve are available for sale as a result of the severe windstorm in the fall of 1950. Considerable of this timber has already been sold and harvested but considerably more remains unsold because of inaccessibility, poor quality, and other reasons.

QUESTION (Roy Carter): What are the speeds for the operation of belts?

E. E. OATHOUT: Experience has shown that coated abrasive belts in the coarser grits can be operated satisfactorily at approximately 5,000 surface feet while belts in finer grits as used for polishing operate satisfactorily at 7,500 sfpm. At least two machine manufacturers now make double belt sanders on which these belt speeds are available. It is suggested however, that the proper grit and abrasive be determined through testing when possible. For some time past the best speed for garnet abrasives has been in the neighborhood of 3,600 sfpm. to 4,200 sfpm. Belts operating above these surface speeds generally utilize aluminum oxide material with better results. The recent introduction of high heat-treated garnet materials has changed it somewhat, as this new type of garnet appears to work most satisfactorily at speeds of about 5,000 sfpm. Once again aluminum oxide appears to work better at speeds higher than the 5,000 sfpm. All of these belt speeds are dependant of course on the condition of the machine, the type of work being done, and once again tests are suggested before specific recommendations are made.

QUESTION (Sherman): When finishes to millionth of an inch are required, what type of sanding equipment would be used?

OATHOUT: Finishes to the millionth part of an inch are in general use with coated abrasive belts in the metal working trades. For example zinc electro engravers plates are finished to a two micro inch finish without difficulty. Two plates are polished at a time using a belt 50 inches wide made of silicon carbide, grit 320. A lubricant is used on the coated abrasive belt thus making it possible to obtain almost a mirror finish. It must be remembered, however, that mirror finishes are not possible with coated abrasive belts as grit lines are always discernable even though grits as fine as 600 are used. There are several manufacturers of machines suitable for this type of work, The Hill Acme Company, Superior Machine Company, Murray-way and Madison have developed machines over the past 18 years for this particular operation. Coated abrasives have gone along with this development and the stainless steel finishes seen in cafeterias, soda fountains, etc. are the result. A more recent development is the use of batteries of machines of this type to finish bumper bars from the raw stock to a point where they can be plated immediately after sanding. They are, of course, formed prior to plating.

QUESTION (Mr. Watson): Do you recommend 1/0 for rough 2/0 for final for panel, or would 2/0 and 3/0 be better?

OATHOUT: If the veneer will stand the coarser grits and give the finish required, grit 1/0 and 2/0 should be satisfactory as better production would be the result. If, however, the veneer is breaking through the finer grits

2/0 and 3/0 would probably prove to be more satisfactory although less productive.

QUESTION (Lawlor): What is the practical tolerance, in thickness, of a 3/4-inch gum panel.

OATHOUT: Three drum sanders as used in the woodworking trade are primarily for surface finish and are not considered to be suitable for sanding to thickness tolerance. In general, drum sanders and coated abrasives would not be used for this operation.

QUESTION (F. T. Parrish): On new No-Fil are there any advantages other than that of the sealer being strengthened?

OATHOUT: Experience with the No Fil Coated Abrasives have been rather limited to date and plant trials would have to be made to prove their adaptability or lack of it on any type of sealer other than DuPont Tufcote. Such trials should be prolonged as difficulties might be encountered with the residue on the coated abrasive being left on the finished piece prior to the final finish, a condition that might cause blooming at a later date. Tests should very definitely be instituted before any decision to use the No Fil papers is made.

QUESTION (Holland): Can grit size be increased by increasing speed of belt?

OATHOUT: When coarse grits are operated too fast burning is generally the result and it appears to be a good rule to stick to the 5,000 sfpm. for coarse materials and 7,500 sfpm. for finer grits. When burning is encountered it can be avoided by cutting back the belt speed. The burning condition is sometimes caused not only by the operation but by the man on the machine as the successful use of any coated abrasive depends primarily on the proper type of pressure. Some machine manufacturers are making machines that operate at 9,200 sfpm. and grits 3/0 and 4/0 are used satisfactorily for polishing at these speeds. Again it appears to be dependent on the type of pressure used by the operator.

COMMENTS (DeSaix, Carborundum Co.): The average speed for flat belt sanding is probably around 9,200 sfpm. Many may operate slower, but it is interesting to note that the larger production plants run their belt machines at 5,500 sfpm. or better. It would appear that the cutting rate of the belt becomes greater as the speed of the belt is increased. Probably a limit can be reached, however, nothing has been conclusively proven that a maximum speed can be reached in sanding of wood. For instance, one company has ordered stroke sanders to be run at the speed of 9200 sfpm. on which they will use 120-3/0 Alo Belts run at 6,500 sfpm. This eliminated a 180-5/0 polishing operation which was required when these machines were run at 4,000 sfpm. The maximum limits of speed will have to be determined only by individual plant, and will have to be determined not only by the grit size used, but by the wood species and the desired finish. Then too, the individual operators have to be trained as to how much pressure they can use. It may be that some of the causes of burning which has been attributed to speed, may actually be caused by a heavy handed operator applying too much pressure.

QUESTION: We have tried fiber backed resin bond materials on our drum sanders and gave up the idea because of the difficulty we had getting the covers on the drums. Have you any tips or suggestions that would make this application easier and quicker?

OATHOUT: Fibre backed resin bond materials can be used satisfactorily on drum sanders. We presume the question refers to the use of 36-inch material transversely on the open-jaw type of sander. Cover application can be made easier by dampening the edges of the covers prior to bending them over a board at the point they are to be inserted in the drum. It is also helpful to skive or rub down the coarser grain along this edge with a rubbing brick or coarse piece of sandpaper prior to applying the cover as such a rub down tends to eliminate the grit binding when the cover is tightened down into the open jaw.

QUESTION: In general, is cloth or paper backed coated abrasive best adapted to edge sanding?

OATHOUT: Either cloth or paper backed coated abrasives can be used for edge sanding and as a general thing garnet abrasives are the best for this operation. Paper can be used where the operation is not too rugged and where flexibility of the coated abrasive is not required. When the operation is really rugged or the coated abrasive is required to flex to any degree, cloth-backed coated abrasives should prove to be the best bet.

QUESTION: In your paper three grains are mentioned as available for use on woodworking operations, garnet, aluminum oxide and silicon carbide. Will you please tell us when each type of grain is used?

OATHOUT: Garnet, the oldest of the woodworking minerals, as used in coated abrasives

DISCUSSION

is still a good standby and it can be recommended with complete satisfaction on drum or belt sanders where speeds do not exceed 5,000 sfpm. Many old timbers prefer garnet on drum sanders as they claim they get a breakdown of the grain that prolongs its cutting, a condition that they do not think they get with aluminum oxide when used on drum sanders. The higher speed drum sanders appear to work more satisfactorily with aluminum oxide grain and as well as the finer grit polishing belts as used to do finer finishes. Silicon carbide is considered to be ideal for hand sanding or small finishing machine sanding operations as it produces proper finishes with excellent productive results. Garnet grain, as always, appeared to give the best results on edge sanders or on end grain sanding due, quite possibly to the type of fracture and breakdown encountered with garnet grain on woodworking operations.

QUESTIONS: What is meant by "hand-rubbed finish"?

R. W. BARBER: This finish is applied after the material has been completely processed, as compared with the usual press-plate finish. It is a rubbed finish and has the texture and appearance of fine, hand-rubbed furniture finish.

QUESTION: Is the NEMA Specification designed to apply to all types of laminates?

BARBER: No. It was designed to cover laminated thermosetting sheets and would not be applicable to soft or rubber-type laminates.

QUESTION (Locke): What is the acid and alkaline resistance of decorative material?

BARBER: Inasmuch as melamine-surface material is generally used, the answer to this will be restricted to melamine-surface materials. These materials are resistant to most of the household reagents. However, the user is cautioned against allowing prolonged exposure to the following reagents: Hypochlorite bleach, hydrogen peroxide solution in any concentration, hydrochloric, sulfuric and nitric acids, lye solutions containing 1 percent or 2 percent lye, sodium bisulphate, potassium permanganate in any concentration, berry juices, such as grape and raspberry.

QUESTION (Koehn): In the application of a decorative material for flooring at Forest Products Laboratory, wa a pattern design or a solid used?

(LOCKE): A solid color was used in this installation.

QUESTION (L. T. BECK): To what extent can the material be applied to curves? What is the minimum radius? Are double curvatures possible? How will heat plasticize the material?

BARBER: Within certain limitations, the material can be applied to curved surfaces. With care, 1/16-inch material can be applied around a 6-inch radius, or the material may be sanded to a 1/32-inch thickness or under and may be formed around a 1-1/2 inch radius. Compound curvatures are not possible. Application of heat and/or pre-soaking is recommended. Heat will plasticize the material, but only slightly. Therefore, postforming of the sheet is possible only to a very limited degree.

QUESTION (Hamilton): When bonding to plywood by hot-pressing, are phenolic glues recommended? What is the critical temperature zone?

BARBER: Yes, phenolic glues are recommended; resorcinol, urea, or other hot-set glues can be used. Excellent bonds can be obtained in temperatures as high as 280° F. However, high temperatures aggravate the problem of "show-through" or "telegraphing" of wood grain, as well as surface marring; therefore, we recommend temperatures somewhat under 200° F.

QUESTION (Clark): What are the electrical characteristics, and is the material suitable for hot gluing by using radio frequency heat?

BARBER: The power factor is in the range of 6 to 8 percent in the "as-is" condition, which is in the same general range as air-dried wood and is, therefore, very adaptable to the application of radio frequency heat.

QUESTION (Clark): What is the relative coefficient of expansion of laminated plastics and plywood? Can the laminate be glued to one side without causing warpage? Can hot-press glues by used for this work?

BARBER: The most important dimensional change is caused by humidity. Both wood and laminated plastics exhibit some dimensional change with change in humidity. Multiple cross band in plywood is quite stable in moisture and may, in some cases, be even more stable than the plastic surfacing material.

We recommend the use of balanced construction i.e., plastic surfacing on both sides. We recognize, however, that many fabricators use one-side construction combined with a sealer on the back and also combined with careful

moisture-content control at the time of bonding and that they usually obtain satisfactory results with this construction.

When hot-pressing, thermal expansion becomes a factor, and it is even more important that a balanced construction be used.

QUESTION (J. S. Horner): Is cigarette-proofing really necessary?

BARBER: For 100 percent protection, yes. Standard materials will withstand burning cigarettes most of the time, but under extreme conditions, such as a fan blowing on the lighted cigarette, they may show burning. The use of a foil layer completely protects against cigarette burns.

QUESTION (Horner): Will the material resist cutting?

BARBER: No. The material has a hard, long-wearing, and abrasion-resistant surface. However, it is not abrasion-proof, and we do not recommend it as a cutting board.

QUESTION: Is the burning of wood as fuel considered as utilization of this material or is it still regarded as waste?

J. HUGO KRAEMER: The use of wood material as a fuel is a legitimate and proper use of wood, provided that it is done in an efficient manner. It is not one of the highest types of use for residue wood, but if it can be utilized in this manner, it will serve to conserve other non-renewable resources, such as coal and oil. Much heat value is lost through the burning of wood with a high moisture content. Pre-drying of the residue wood before burning would make its use as fuel much more efficient.

QUESTION (Caldwell): Why push the use of wood and wood products as long as metals seem to be less critical, or more readily available?

KRAEMER: The use of wood and wood products should constantly be promoted by all members of the industries concerned -- not only for the protection of their own business interests, but as a means of conserving our national supplies of the non-renewable resources. This should be aggressively carried on even in times when demand may exceed supplies of wood and wood products.

QUESTION (Norton): How can wood-using industry utilize other existing research and development facilities in case they do not have or cannot afford such activities within certain individual companies?

KRAEMER: The first step for an individual company would be to contact the department or faculty of wood utilization at the school of forestry in the state, or the nearest to the company. Most schools can take on research for outside interests under contracts. There are also a number of private research laboratories which will investigate specific problems on a contract basis.

QUESTION: How can wood-using industry find out about research results which may be of use in its operations?

KRAEMER: The research carried on in government (State and Federal) and academic institution laboratories is usually fully reported in bulletins, papers presented before meetings of societies such as the Forest Products Research Society and the Society of American Foresters, and in articles written for trade and professional journals. The Forest Products Laboratory at Madison, Wisconsin, the Northeastern Wood Utilization Council, the Washington Institute of Forest Products and the Oregon Forest Products Laboratory, just to name a few, issue periodically the results of research. A logical starting point for any concern woudl be the members of the wood utilization staff at the nearest school of forestry. There is, of course, a good deal of industry research which is not published. This is unfortunate for it leads to a good deal of duplication.

QUESTION (Parrish): Ironbark (eucalyptus) is on the Basic Materials list as a scarce item. Is this blue gum?

KRAEMER: That may be one of its common names. However, Ironbark is the most used and is preferred. It is not one species but two or three - usually Eucalyptus paniculata, E. crebra and E. siderophloia.

QUESTION (Carter): What is Ironbark (eucalyptus) used for?

KRAEMER: Because of its generally high strength properties, particularly its hardness and resistance to abrasion, it has been used for railroad ties, bridge construction, fence posts, etc. in Australia. Its principal use in this country is in ship construction, usually as sheathing for such ships as ice-breakers.

Veneer Flooring[1] [2]

BRUCE G. HEEBINK, Engineer, Forest Products Laboratory,[3]
Forest Service, U. S. Department of Agriculture

INTRODUCTION

Early in 1950, the U. S. Forest Products Laboratory and the Housing and Home Finance Agency began a cooperative study of the problem of suitable flooring materials for low-cost homes. A need for this study was indicated by the lack of acceptable flooring available at a price permitting its use in low-cost housing. Accordingly, observations on flooring practices used in the construction of low-cost houses in the United States were made by personnel of the Forest Products Laboratory.

In brief summary of this rather extensive survey, two outstanding trends are cited: (1) a strong preference for a wood floor, and (2) the increasing popularity of concrete floor-slab construction. Normally wood floors laid over a concrete slab are rather expensive, often being of the strip type laid on screeds or mastic imbedded pieces, or the parquet block or herringbone type laid in mastic. Both of these are considerably thicker than floor coverings such as asphalt tile or linoleum often used in adjacent floors; often a thin flooring material would be more suitable. As a result, primarily because of its low cost, asphalt tile currently appears to be the most popular flooring material for the low-cost home built on a concrete floor slab. There is a definite need and a ready market could probably be found for some type of inexpensive thin wood floor covering which could be laid directly on a concrete slab above grade.

In the course of the resulting evaluation and development program on flooring for low-cost houses carried on in cooperation with the Housing and Home Finance Agency in 1950 and 1951, the Forest Products Laboratory developed and evaluated in a preliminary manner a veneer flooring which, it was thought, could be laid in mastic directly on a concrete slab or plywood subfloor.

[1] A contributed paper to the Journal of the Forest Products Research Society.

[2] The patent status of the veneer drying process described in this article has not been thoroughly investigated.

[3] Maintained in Madison, Wis., in cooperation with the University of Wisconsin.

CONCEPT FOR A NEW FLOORING MATERIAL

Undoubtedly, many attempts have been made to develop a satisfactory flooring from veneer, and there is currently available at least one type of veneer tile flooring made from sawn veneer. However, since no record of the use of rotary-cut or sliced veneer could be found, and since the flooring proposed by the Forest Products Laboratory is a partially stabilized veneer, a full-scale service trial under typical use conditions appeared to be justified. Any attempt to use normally dried veneer sheets bonded to a concrete subfloor with the ordinary type of asphaltic-base mastic would almost certainly result in failure. If the veneer could be made somewhat flexible, with its tendency to shrink and swell somewhat reduced, however, the resulting product, when bonded to a concrete slab with a high-quality, rubber-base mastic, might well be acceptable flooring under normal use conditions.

SPECIAL DRYING PROCESS

A special drying process was employed to prepare the veneer for the experimental floor.

A ventilated caul of 1/4-inch aluminum plate 20 by 40 inches in area was made by drilling 1/8-inch holes on 1-inch centers in both directions and connecting these holes by 1/8-inch-wide slots milled half-way through the 1/4-inch plate from the back side (Fig. 1). A 16-mesh copper screen was laid on this special caul, and the veneer to be dried was placed on the screen and in turn covered by a 1/8-inch-thick stainless steel caul. Green 1/8-inch rotary-cut yellow birch veneer directly from the lathe was cut into sheets approximately 20 by 40 inches in size. The sheets were dried, one at a time, in a hot press in the special caul assembly for 15 minutes at a temperature of 300° F. A pressure of 100 psi. was used to restrain the veneer. Upon removal from the press it was found that the moisture content of the veneer was approximately 2 to 3 percent and that the shrinkage across the grain was practically negligible (1/16-inch on a 20-inch width).

The sheets were found to be exceedingly flat and to have a rather flexible feeling as

compared to matched veneer from the same bolt dried in a continuous roller drier in the normal manner. These sheets were then conditioned to approximately 6 percent moisture content and cut into strips 3 inches wide and of random length varying from 20 to 40 inches. The strips were slightly beveled at the edges and lightly sanded, then given two coats of a clear sealer to prepare them for laying as shown in Figure 2.

LAYING THE TEST FLOOR

The office selected for the test had a painted concrete-slab floor. Before the veneer was laid, therefore, it was necessary to remove all the paint from the concrete with paint remover. A rubber-base mastic was applied to the concrete slab, a small section at a time, at the rate of about 1 gallon for each 100 sq. ft. of slab area with a conventional notched spreader. The mastic was allowed to dry for about 10 minutes to become properly tacky before the veneer was laid. The flooring strips were then laid on the mastic-coated floor much as asphalt tile are laid (Fig. 3). The strips of veneer were merely laid in place and pounded with a rubber mallet to assure contact with the subfloor. It was occasionally found necessary to use weights to hold slightly warped pieces of flooring in place until the mastic bond was formed. The moisture content of the flooring at the time of laying was approximately 6 percent. The strips were laid as tightly as possible, with no cracks left intentionally for expansion. The center portion of the floor (approximately 5 feet wide) was laid in November 1951, and the remaining edge portions were laid in January 1952. The completed floor was given one coat of floor wax and buffed with a mechanical buffer. The finished floor is shown in Figure 4.

EARLY BEHAVIOR

A record of the moisture content of a 100-gram spruce "sliver" hung in the office is being kept. The moisture content of this sliver dropped to approximately 3-1/2 percent shortly after the test floor was installed. No opening of the joints between the strips was noted at this low humidity. It was assumed, therefore, that the mastic bond was sufficiently strong and rigid to resist the shrinkage stresses of the veneer. The moisture content of the "sliver" in the room has been rising gradually throughout the spring and summer months until recently (about July 1) it reached 10 percent. A careful inspection of the floor at that time revealed 2 or 3 small blistered areas. It had previously been noted that these areas were unbonded, as revealed by tapping, and therefore the blisters appear to be the result of expansion of veneer that was not restrained by the mastic bond. Wherever the veneer was initially bonded to the subfloor the performance has been entirely satisfactory, and the appearance has remained unchanged to date in spite of rather hard use.

Without the benefit of adequate control tests on normally dried veneer, the key to the satisfactory performance of the experimental veneer flooring to date might be assumed to be the special drying process. It could be argued, however, that the excellent adhesion of the rubber-base mastic used would restrain the tendency of normally dried veneer to shrink and swell sufficiently to provide satisfactory performance.

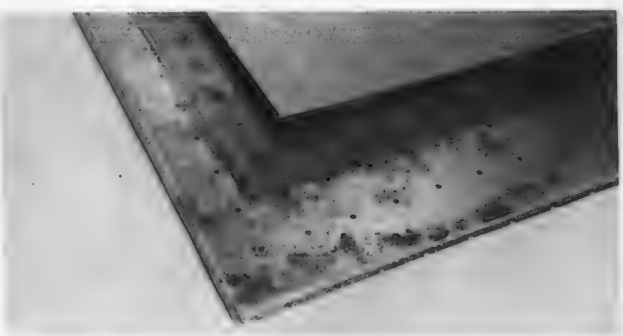

Figure 1.--Veneer with caul and screen used in the special drying process.

Figure 2.--Veneer strips ready for laying. Reverse side of strips, as seen in two strips crossing the others, show pattern of screen used in drying.

Figure 3.--Experimental floor partially laid.

Figure 4.--Appearance of the finished floor.

JOURNAL of the FOREST PRODUCTS RESEARCH SOCIETY

Trigonometry for the Chair Builder[1]

Martin H. Hirsch, Secretary-Treasurer,
Hale Company, Inc., East Arlington, Vermont

THE TROUBLE WITH CHAIRS

Many a casegoods expert or patternmaker may get confused when it comes to the building of a chair. It is not so much that the raw materials or methods used are different, but the difficulty lies in the odd angles at which nearly every chair part has to be cut to length.

Most parts in a case piece are cut to length at an angle of 90°. The casegoods designer has a simple job at his drawing board. He supplies front, side and top views from which the appearance of the final product can easily be judged. The patternmaker and jig builder can measure the dimensions of every part without difficulty. Setting the machines and checking the set-ups are comparatively easy, in most instances only an accurate rule and a square are needed.

Chairs, in particular those with bent or curved parts, present a much more complicated problem. Looking at the back part of the chair shown in Figure 1, it will be obvious that each of the four horizontal back pieces is of a different length, and that each of these parts is cut to length at a different angle horizontally and vertically. A schematic view of such a backpart is shown in Figure 2.

I have worked with many a furniture designer, but when it came to chairs, they either supplied a nice looking perspective sketch only, or a full-size drawing, showing all parts correctly from a draftsman's point of view. Neither gives a satisfactory presentation of the finished chair, nor is of much help to the patternmaker in building the chair itself or the production jigs.

The usual way the patternmaker will build a chair, in particular the back part, is about as follows: The two back legs are clamped into position, with the right separation at the top, seat, and floor level, and the proper backward pitch of the chair. Then horizontal back slats are fitted into this mock-up of the back assembly. This is a tedious job, as each backslat has to be cut down gradually so as to fit exactly and produce a proper and tight joint. Once a perfect fit has been accomplished, the perfected parts are generally used as samples for future machine set-ups. Although these

Figure 1

sample parts may be treated to make them impervious to moisture, they nevertheless will change their shape and future cuttings, while each part produced may be a perfect replica of the "sample", will not give the exact fit, that is necessary if filling open joints with wood dough is to be avoided.

METHOD FOR DEVELOPING ACCURATE MEASUREMENTS

Realizing that such antiquated methods are not compatible with principles of up-to-date production, I have attempted to develop a method for eliminating trial-and-error proce-

[1] A contributed paper to the Journal of the Forest Products Research Society.

dures in patternmaking, at the same time furnishing the machine department concrete information expressed in inches and degrees, instead of a wooden sample piece.

Being the most involved and complicated assembly, this article deals only with the

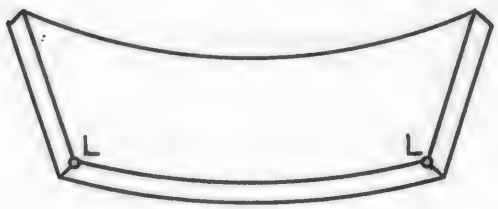

Figure 2

chair-back assembly found in a full steam-bentwood chair. Back assemblies, as made for lower priced box-seat type chairs, can of course be calculated by similar methods.

As most chair producers standarize the position of the two back legs, (in which case only the height of, and the design between the two back legs varies), the basic information regarding the position of these back legs has to be calculated once only and the lengths and cutting angles of the inserted slats can be found with little effort.

Ideas and formulas used in this paper are based on simple plane trigonometry, and the only additional help necessary is a table showing "Natural Sines and Cosines", as found in any elementary trigonometry book. In order not to make this article overlong or unwieldly, only final formulas are quoted for each problem.

The basic working tools of the method described in this article are the two extended planes of the back legs, the line where these two planes cut and the angle between these planes. (See Figure 3)

To establish uniform procedure we selected the inside faces of the back legs. These two faces extended towards the front of the chair will form two planes, which will meet and cut in the "centerline".

The centerline will lie very close to the chair backpart, if the back legs are strongly turned inwards. When bent horizontal back slats are used, this will contribute to the production of a very comfortable, back fitting chair. If the two back legs are parallel, not twisted at all, the centerline of course will be at infinity. Other factors being equal, the centerline will be further removed from the backpart, if the back legs are farther apart, for instance in the case of an armchair's back part. The centerline will have a tendency to lean toward the back part at an angle if the chairback leans backwards, or if the chair seat is higher in the front than in the back. This too will add to the sitting comfort and will help to avoid stiff looking, straight sitting chairs. Finally, the centerline will have a tendency to lean away from the backpart if the distance between the back legs on top of the chair is greater than this distance at floor level.

Once a certain experience is acquired, it is possible to lay out on paper the relationship between the back legs and the centerline, but in the beginning I would suggest getting this information from an existing, full-sized chair.

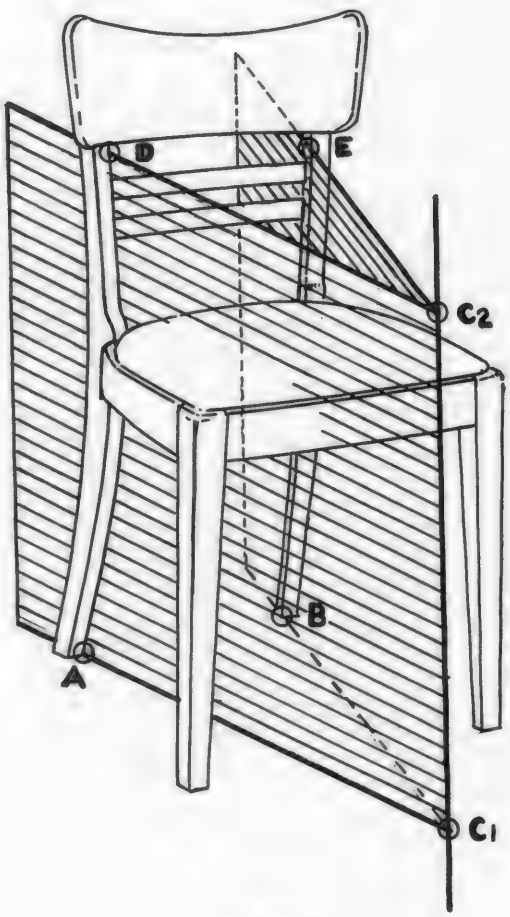

Figure 3

STEPS IN THE PROCEDURE

For going about this, the following steps are suggested:

(1) Make a full-sized, exact drawing of the back leg to be used. (See Figure 4)

(2) Using a plumb line, held to the top, back edge of the back leg (R2), find the distance from R2 to the touching point of the plumb line on the floor (T). Also find the distance between point T and the bottom rear edge of the back leg (R1). Using a compass, find point T in the full-sized drawing of the back leg and then draw the floor line (R1 T) and the plumb line (R2 T). The angle between these two lines will of course be 90 degrees.

(3) Using the full-sized chair sample, take two thin, straight wood or metal rulers and hold them at floor level against the inside faces of the two back legs. (See also Figure 3). Measure the exact distance, at floor level from the inside front corner of the back legs (points A and B) to the point, again at floor level, where the two rulers will touch. (point C1). This distance should then be measured off on the back leg drawing, beginning at point A or B along the previously established elongated floor line. This will result in point C1, the first point of the centerline.

(4) With a pencil mark the inside front corners of the back legs at exactly the same height, about 30 inches from the floor (points D and E). Mark the same correct distance from the floor also on your back leg drawing.

(5) Again using the sample chair and the two rulers, hold them flat against the inside face of the back legs, at points D and E as marked before. Hold the rulers horizontally, parallel with the floor, and measure the exact distance between point D, or E and the point where the rulers will touch. This is point C2, the second point of the centerline.

(6) Going back to the drawing of the back leg, trace a line through D and E, parallel to the established floor line. Mark on this line point C2, taking the distance found in step 5.

(7) Connect points C1 and C2. This is the centerline of your chair back part.

(8) Measure and make a note of the distance between the inside front corners of the back legs at floor level, that is the distance between A and B (See Fig. 3).

(9) On your sketch of the back leg, draw a line through point A or B at a right angle to the centerline. Where this new line cuts the centerline, establish point C3. Measure and make a note of the exact distance between point A or B and point C3.

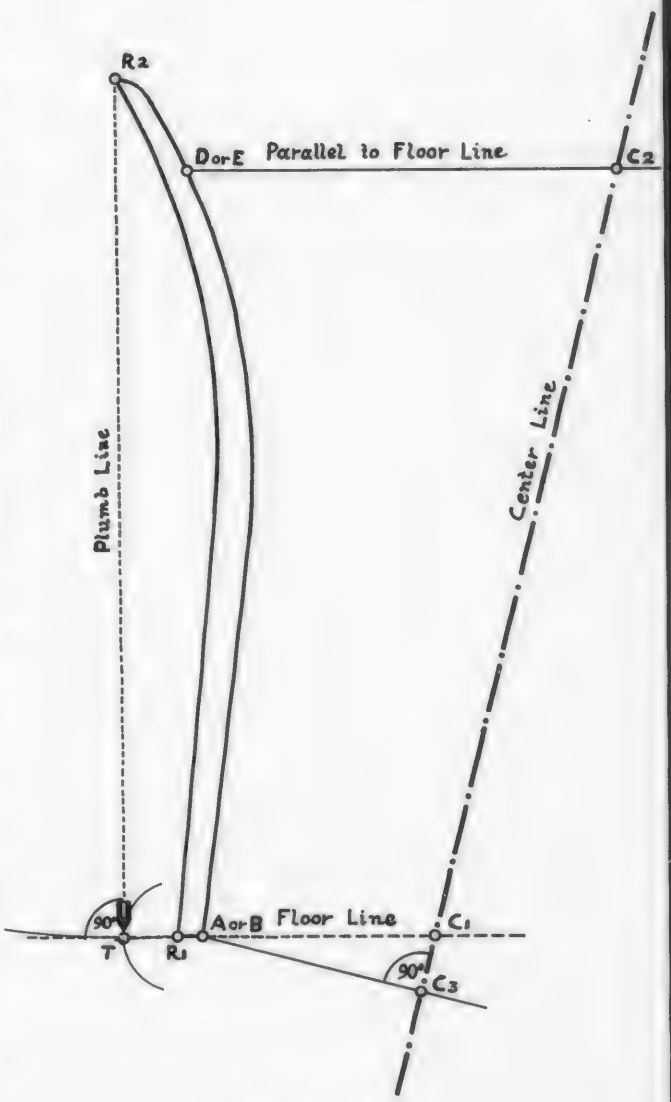

Figure 4

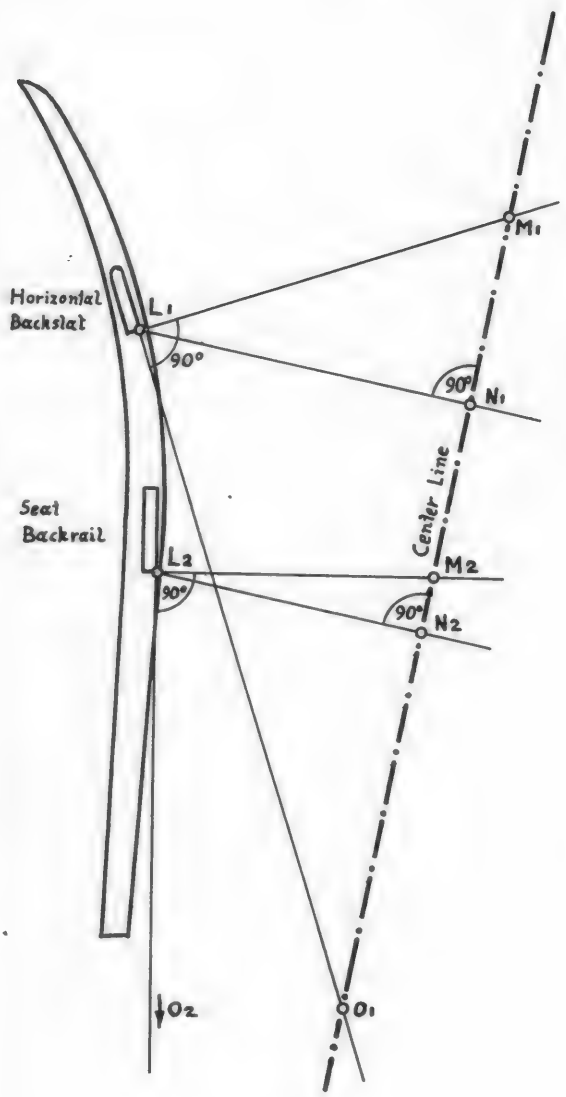

Figure 5

You now can erase all lines or information on your drawing, except the back leg, the centerline and points C1 and C3.

Now you are ready to start drawing into your back leg sketch the different back slats, the seat rail or a possible stretcher. Care should be taken to have these partsmarkedin their exact location, corresponding with dowel holes or mortises in the back leg. (Figure 5, for simpler presentation, shows only one back slat and the seat rail.)

After having marked the back slats and other cross members in your drawing, proceed as follows:

(10) Extend the front face of each slat until this extended line cuts the centerline. The front face extension of the horizontal back slat will cut the centerline in point 01. The front face extension of the seat backrail will cut the centerline in point 02, far off our drawing board. Never mind, a special formula is quoted to take care of this "lost" point. Then, when possible measure and make a note of the distance L to 0.

(11) Extend the lower face of each slat, up until it intersects the centerline in point M1 or M2. This line of course will be at a right angle to the line drawn in step 10. Then measure and make a note of distance L to M.

(12) Draw a line, perpendicular to the centerline, through points L1 and L2, the lower front corner of each slat. This will give you, located on the centerline, points N1 and N2. Then measure and make a note of the distance L to N.

In order to find the distance "X", (see Figure 6) as well as the angles "a" and "b" of each slat, use the following formulas. (Note that Figure 6, for purposes of simpler demonstration shows the backslat turned upside down.)

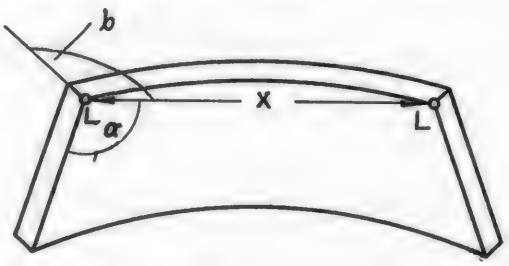

Figure 6

T find distance "X":

$$\text{"X"} = \frac{(A\ B) \times (L\ N)}{(A\ C3)}$$

To find angle "a":

$$\cos (180° - \text{"a"}) = \frac{(A\ B) \times (L\ N)}{2 \times (A\ C3) \times (L\ O)}$$

To find angle "a", if distance (L O) can not be measured, find distance (M N) on your drawing, then:

$$\cos (180° - \text{"a"}) = \frac{(A\ B) \times (M\ N)}{2 \times (A\ C3)\ c\ (L\ M}$$

To find angle "b":

$$\cos (180° - \text{"b"}) = \frac{(A\ B) \times (L\ N)}{2 \times (A\ C3) \times (L\ M)}$$

For values corresponding to distances (A B), (A C3), (L O), (L M), and (L N), see steps 8, 9, 10, 11, and 12 respectively.

Once the distance "X", as well as angles "a" and "b" are found, a simple template can made to assure uniform machine set-ups and production. These templates can be made from steel, brass or aluminum sheets, fairly heavy gage to prevent bending or straining. The distance "X" and the angles "a" and "b" are cut from the template as shown in Figure 7. In order to avoid inaccurate measurements due to wood fuzz along the edges, it is suggested that the corners be cut out as shown in Figure 7.

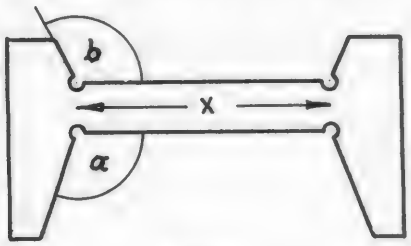

Figure 7

I fully realize, that the method of chair back building described in this article is radically different from methods used in the past, but my experience shows that, once tried out and adopted, this method will solve innumerable headaches for the designer, pattern-maker, and foreman and will assure not only lower production costs but also uniformly high accuracy.

JOURNAL of the FOREST PRODUCTS RESEARCH SOCIETY

Important Progress in the Timber Fabricating Industry[1]

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Arch Rib Truss Corporation, Los Angeles, California

SUMMARY

The American Institute of Timber Construction has just been formed as a nonprofit corporation. Its membership will include active fabricators of engineered timber and glued laminated assemblies and structures, together with individuals, firms, associations and societies whose interests and activities are kindred. It will fill a much needed position in this important industry not only in discharging the customary functions of a trade association, but in serving as an industry liaison agency with research and evaluation activities. This will introduce a significant focal point for engineering developments and produce a means for obtaining acceptances of worthy developments by architects, engineers, contractors, public agencies and other users.

GROWTH OF THE FABRICATING INDUSTRY

Wood was the dominant construction material many centuries before the advent of modern technology. Its history is one of superior service in all manner of structures, of great beauty in fine edifices, and of universal availability and utility to its users. Only during the current century, however, have we started to understand wood and its applications technically.

The timber fabricating industry as we know it in this country is approximately 25 years old. It started humbly and grew methodically as mechanical equipment and devices became available, shop methods were evolved and experience was gained. Most of the pioneers are still living and are busily engaged in their practices. Their reminiscences are fascinating. Their convictions as to the future of the industry are among the strongest votes of confidence in American resourcefulness and progress.

It is significant to note that many of the industry's products and practices have come about through evolution on the job with improvements propted by experience. The foreman, the designer, and the worker have all contributed much. An example is the wood bowstring truss that has been a major contribution to the construction industry. It has structural efficiency, overall suitability and genuine economy. In its present form it utilizes laboratory fundamentals from scientifically trained men, sound designs by experienced engineers and the know-how of workers in the shop and field. Let us not lose sight of the latter in the fast pace of the scientist and engineer and our modern concepts of research and development.

Among other twentieth centure developments are the modern timber connector, originating in Europe where need existed for connections and fastenings to utilize more fully the strength of wood members of diminishing availability. The connectors which we now use, however, represent the combined efforts of researcher, evaluator, manufacturer and user.

Glued laminated structural members, too, had a modest beginning. Now, because of extensive research, tremendously improved lamination techniques, plus the development and use of adhesives which permanently bond the laminations together, the industry is in a position to supply all manner of requirements.

Let us recognize that the developments of industrial firms are no more significant than the extent to which they are accepted by others. Products require acceptance, In an industry as basic as timber fabricating, the combined efforts of the entire industry are essential. The following current example is revealing.

During World War II the Army and Navy required a tremendous number of wood roof trusses for warehouses, hangars and myriad other structures. Wartime exigencies resulted in a program that was below what is now known to be acceptable levels of design, materials quality, fabrication and erection. This wartime effort was huge and was completed on time. Many projects were brilliantly conceived and executed. Many others, as indicated, left much to be desired. The consequence of a lack of coordinated advance planning in the latter group was a serious maintenance problem.

[1]Presented at meeting of Forest Products Research Society, Northern California Section, San Francisco, California, May 9, 1952.

This matter is discussed quite freely, for neither the military nor the fabricating industry is accusing or accused. Instead, both are seriously seeking and are well on the way toward evolving a basis that will insure against a recurrence of the situation in either peace or war.

As mentioned, the fabricating industry is not blamed for the deficient grades and high moisture contents furnished from wartime stockpile, nor for the structural designs that are now known to be subject to important improvements, nor the errors in construction, nor the overloadings, nor the the fact that some temporary structures have become permanent. In fact, our industry is given high commendation for its significant share of the wartime load. But the fact remains that much must be accomplished in order that the Armed Services may have the benefit of the best in designs, with materials that meet well considered specifications, not contractor-built on the job but shop-fabricated by firms of high integrity; not with a fabricating industry that is an aggregation of individuals but with an industry that has established and maintains high standards. This problem has been placed squarely in the lap of the fabricating industry. The challenge has been accepted.

GENESIS OF THE INSTITUTE

In San Francisco on April 29th and 30th, 1952, the American Institute of Timber Construction was formed as a non-profit corporation. Its membership will include active fabricators of engineered timber and glued laminated assemblies and structures, together with individuals, firms, associations, and societies whose interests and activities are kindred to the aims and objectives of the Institute.

President is Mr. Ward Mayer of Timber Structures, Inc., Portland, Oregon. Board members comprise: Mr. Charles C. Calvert, Summerbell Roof Structures, Los Angeles; Mr. C. W. Knoll, Roof Structures, Inc., Webster Groves, Missouri; and Mr. Val Gardner, Miller-Gardner Fabrication Co., Monroe, Oregon. The author of this paper is serving as Secretary-Treasurer and, temporarily, as Executive-Manager. A headquarters will be established in the near future in the middle West or East.

A Code of Standard Practice and Standard Specifications are in preparation. Committees are already at work. The Institute, barely a week old at the time this is written, has built a solid foundation and its superstructure is is already visible. It is expected to grow rapidly.

The aims and objectives of the Institute include, but go beyond, those of many trade associations. They have much in common with the purposes of a technical society. In an industry that has grown so rapidly that textbooks have not been able to keep pace, it is obvious that there is much to be accomplished as rapidly as circumstances permit.

One example of a direct challenge to the Institute is the subject of fire safety, a much misunderstood, abused and sometimes ignored subject. The statements that wood burns and that steel is "incombustible" are misleading when applied to the fire safety of a building. So many factors are involved that only a few can be mentioned in this paper. The fire resistance of a material is not measured entirely by its combustibility or non-combustibility. The collapse or failure of a material under fire conditions is not always the result of ignition. Heavy timber construction has a remarkably good record of fire safety. Glued laminated members are equivalent if not superior to sawn timbers of the same nominal size. The thermal expansion of wood is negligible. Its insulating value is so high that even when a portion of a member is burning the uncharred portion is practically at room temperature and retains its strength. These and other factors prove conclusively that timber construction merits greater recognition as a fire-safe construction material.

With further regard to fire safety, there is much yet to be learned concerning fire retardant treatments, flame spread and flame retardant applications, automatic sprinklering and structural improvements. Many years ago the Underwriters' Laboratories found that a masonry column cap would enhance the fire safety of a wood column. To date, that finding has not been developed and utilized. These are items on which the Institute can lend assistance.

Before closing it is appropriate that a thoughtful consideration be given to the future. It is reasonable to assume that progress can be more rapid during the next 25 years than during the like period preceding. Fortunately, forestry has also taken rapid strides to the extent that sustained yield is being accomplished. Timber is our country's only replenishable source of building materials. Tomorrow's roof trusses are already well "stockpiled" in the forests of America.

Abstracts

The preparation of abstracts from world literature in many languages is so highly specialized and costly that the Forest Products Research Society has no abstracting service of its own. For the abstracts in this issue of the JOURNAL the Society is indebted to the respective abstract journals indicated, from which they have been selected with the kind permission of the editors. Readers wishing information in addition to that given in these abstracts should consult the original articles referred to. Copies or additional information cannot be supplied by F.P.R.S. or the abstract journal. The journals from which abstracts are published in this issue are as follows:

BULLETIN OF THE INSTITUTE OF PAPER CHEMISTRY, published monthly at Appleton, Wisconsin by the Institute of Paper Chemistry, subscription price $25.00 per year. This Bulletin publishes over 3600 abstracts per year on subjects of interest to manufacturers of pulp, paper, fiber board and allied products.

CHEMICAL ABSTRACTS, published semimonthly by the American Chemical Society, Executive Office - 1155 Sixteenth Street, NW, Washington 6, D. C., subscription price $60.00 per year plus postage. This abstract journal publishes many thousands of abstracts annually with broad coverage of world literature in the entire field of chemistry and allied subjects.

FOREST PRODUCTS AND UTILIZATION ABSTRACTS are published quarterly by the Commonwealth Agricultural Bureaux of London, England, as a separate reprint of decimal sections 3, 7, and 8 of Forestry Abstracts, for the facility of those interested chiefly in the field of wood utilization. The abstracts are prepared by the Commonwealth Forestry Bureau, Oxford, England, and the utilization section contains about 1,200 titles and abstracts per year from literature in some 30 languages and cover all aspects of forest utilization from cutting and extraction through marketing, mechanical, and chemical processing to minor forest products. F.P.R.S. members interested in securing the complete issues of Forest Products and Utilization Abstracts should communicate with the Secretary of the Society.

TECHNICAL BULLETIN OF THE FURNITURE DEVELOPMENT COUNCIL is published bimonthly by the Council at 11 Adelphi Terrace, London W. C. 2, England. The Technical Bulletin publishes hundreds of abstracts and reviews from world literature annually, relating to the various phases of the furniture manufacturing industry. Subscription price is $5.00 per year.

GENERAL

Bois tropicaux africains. African tropical timber. Organisation for European Economic Cooperation, Paris. 1951. pp. 421. (F.E.) Price 9s. (obtainable from H. M. Stationery Office.)

This publication is an addendum to the report 'Possibilities of increasing the use of tropical timber' published in December, 1950 (cf. For. Abstr. 12 (No. 2964)). Part I consists of a single alphabetical list (vernacular and botanical names) of African tropical timbers giving vernacular English, Belgian, French, Dutch and Portuguese names for each species together with its category in the general classification adopted in the above report, i.e.: (1) slicing and/or peeling, (2) light hardwood, (3) heavy hardwood, and (4) sleepers. Part II gives for each country responsible for overseas territories in Africa (Belgium, France, Portugal, United Kingdom) information on the principal tropical timbers produced by those territories, i.e. density, colour, texture, grain, and possible uses, together with information on actual or possible exports. This is a provisional document liable to expansion and revision. (For. Prod. Util. Abs.)

Canadian woods--their properties and uses. Forest Products Laboratories Division, Forestry Branch, Ministry of Resources & Development, Ottawa. 2nd ed., 1951. pp. xv + 368. Many refs. Price $3.00.

Contains the following chapters: Canadian woods--general (J. H. Jenkins); Commercial timbers of Canada (T. A. McElhanney); Classified uses of Canadian woods (J. B. Prince); Structure of wood (J. D. Hale); Mechanical and physical properties of wood (W. E. Wakefield); Seasoning of lumber (R. S. Millett); Decay and stains in wood (C. W. Fritz); Preservative

treatment of wood (J. F. Harkom); Chemical utilization of wood (C. Greaves and H. Schwartz); Secondary wood-using industries (J. B. Prince); Veneers, plywoods, and wood adhesives (D. G. Miller); Glues and gluing (E. G. Bergin); Dielectric heating (R. W. Peterson); Glued, laminated construction (D. E. Kennedy); Shipping containers (W. Butterworth); Timber fasteners (J. M. Rudnicki); Pulp, paper, and related products (W. Boyd Campbell). (For. Prod. Util. Abs.)

Besley, Lowell. Potential international timber supply. Can. Pulp Paper Ind. 5, no. 4:118, 120, 122, 124, 126 (April, 1952).

The supply of timber from forest producing and exporting regions of the world is summarized, and the extent to which the production of these regions will compete with wood which is produced in Canada as a whole, and British Columbia in particular, is analyzed. 3 illustrations and 9 references. M.W. (Bul. Inst. Paper Chem.)

PROPERTIES OF WOOD

Ugrenović, A. Drvo za rezonanciju od Stradivarija do danas. (Resonance wood from Stradivarius to the present time.) Predavanja odrzana u Jugoslavenskoj Akademiji No. 5, 1951. pp. 38 + 13 photos. 34 refs. (Croat.) Published by the Jugoslavenska Akademija Znanosti i Umjetnosti, Zagreb.

Analyses the role of the various constructional parts of a violin and the properties desirable in their materials for good performance. The early centres of violin-making were developed in regions where Spruce (Picea abies) and Fir (Abies alba) forests were plentiful (Northern Italy, France, Bavaria, Saxony, Bohemia) because the wood of these species, especially Spruce, is the most homogeneous and isotropic of all European woods. In the first period, other species were also used, e.g. Pear, Lemon, and Ash. The main relevant property of Spruce wood is its high modulus-of-elasticity/sp. gr. ratio, responsible for the high conductivity of sound waves. The homogeneity and isotropic nature of Spruce wood depend on the tracheids being very long and forming up to 95% of the wood. Graphs are included showing how in Spruce (1) both the sp. gr. of the wood and the % of summerwood decrease as the width of the annual rings increases (2) both the sound velocity and the modulus of elasticity increase together with the sp. gr., and (3) the velocity of sound increases with the pitch, and decreases as the wood's moisture content increases. (Cf. For. Abstr. 8 (No. 2627).) (For. Prod. Util. Abs.)

TONKIN CANES AND RATTANS

R. H. Kirby, World Crops, Vol. 3 No. 1, January 1951, pp. 5-7, 13, 4 illus, 9 refs.

Tonkin canes are the culms of a species of bamboo (Arundinaria amabilis) which grows only in a certain district of China. The canes, which are known locally as tea stick bamboo, are of particular value because of their straightness and toughness. They grow to a height of 50-60 ft. Small crooks in the culms are removed by heating gently and straightening while warm. This heat treatment has the further advantage of destroying the powder post beetle which attacks the canes. Protection against the insect can also be afforded by washing with a 5% solution of D.D.T in Diesel fuel oil. In European markets the culms are graded according to thickness and length.

Rattans are the stems of various climbing plants, the most important commercial species being Calamus and Daemonorops obtained from the Far East. The stems grow to a length of 500-600 ft or more, and after harvesting they are dried in the sun, cut into lengths of about 16 ft, sorted, washed and scoured. The stems are bleached by the sun or by treatment with sulphur. The best rattans should be strong, light, flexible, light yellow in colour and of uniform thickness. They should have a smooth surface and should resist breaking and splitting when twisted or bent.

Malacca canes are the stems of a rattan palm, Calamus scipionum, which has few but very long stems with a wide distance between nodes. The thickness of the stem varies from 1/2 to 1-1/2 in.

Attempts have been made to market rattans from W. Africa but these are generally of a poorer quality and are not likely to be of importance when supplies from the Far East are adequate. (Tech. Bul. F.D.C.)

TIMBER HARVESTING AND LUMBER MANUFACTURE

DeMoisy, R. G. Relogging to portable utilization plant. Circ. Inst. For. Prod., Wash. No. 13, 1951. pp. 4.

A plant consisting of an electric generator, a drag saw, a splitter, and conveyors, and employing 10 men, is being used to process logs so defective that they are not tallied in the Institute's Unused Wood Inventory in 1949. Clear bolts of wood are split out from diseased,

rotting and otherwise defective Hemlock and Douglas Fir logs, and loaded in bundles on a truck with dual rear-axle drive and dual-axle wagon-type trailer. Records for a week showed 11 - 12-1/2 cords per unit load. (For. Prod. Util. Abs.)

Bryant, B. S. Knot plugging to up-grade lumber. Circ. Inst. For. Prod., Wash. No. 16, 1951. pp. 4. 6 refs. (For. Prod. Util. Abs.)

VENEER AND PLYWOOD

India's plywood industry. Timb. Tr. J. 200 (3930), 1952 (109).

Gives brief particulars of the number of factories and their potential output, and the estimated future demand for tea-chests and commercial plywood. (For. Prod. Util. Abs.)

Saks, E. V. White Birch moves to the veneer front in Canada: Veneers & Plyw. 45 (9), 1951 (26, 28-9). P.R.

The shortage of Yellow Birch peeler bolts in Eastern Canada is bringing White Birch into greater use. Two new veneer mills have been erected in the White Birch region and are starting production in autumn 1951. Exact calculations of the amount of White Birch in North America are not available. According to Newfoundland sources, that country has a thousand million bd. ft. of Birch of 10 to 18 in. diameter. In Northern Quebec and Ontario many woods are 50% White Birch. Peeling and transport methods used in Scandinavian countries are described. (For. Prod. Util. Abs.)

Knight, R. A. G., Carruthers, T. F. S., and Thomas, A. M. The Risborough Naiad: a continuous-operation oven for moisture content determinations upon veneers. Wood 16 (11), 1951 (416-7).

The Naiad, developed at the Forest Products Research Laboratory, Princes Risborough, consists of a frame bolted to the wall and carrying two banks of infra-red lamps between which the 6-in.-square veneer samples that have been cut from the sheets under test are carried by clips attached to a chain conveyor. The samples are weighed before they are put into the clips; after drying, they are automatically released by a trigger plate and fall into a chute from which they are collected for the final weighing. The weights and reference numbers are written on the samples themsleves, to reduce paper-recording. A single determination can be made in 10 min. or 40 in 1 hr., as against several hours needed to dry a sample in an ordinary oven. The amount of radiation is controlled by varying the number of lamps, so that veneers of different thickness, species, and initial moisture content can be dried without scorching or igniting. Tests on samples of veneer from 6 species--Afara (Terminalia superba), Beech, Gaboon (Aucoumea klaineana), Sapele (Entandrophragma sp.) and Binuang (Octomeles sumatrana)--dried in the Naiad with 3 to 9 lamps per bank, showed that for 0.064-in. veneer the Naiad moisture content with 5 or 6 lamps in use, agreed to within about 1% with that found by conventional oven-drying. Figures showing the effect of species and of thickness on error in moisture content for different numbers of lamps, and the relation between veneer thickness and the number of lamps required for Beech, are given in graphs. The Naiad has been in use at Princes Risborough since 1950, and systematic checks against conventionally dried samples have shown that its performance is consistent. It is not obtainable commercially, nor is it covered by patents; the prototype can be examined at the Laboratory on application to the Director. (For. Prod. Util. Abs.)

GLUES AND GLUING

Radio frequency edge gluing. Timb. Tr. J. 199 (3919), 1951 (451-2).

The G.E.C.-Fielding edge-gluing machine has been developed jointly by the General Electric Co., Ltd., Magnet House, Kingsway, London, W.C.2. and by Fielding and Platt, Ltd., Atlas Works, Gloucester, for the production of timber panels and blockboards 36 to 80 in. in length, up to 40 in. in width, and from 3/8 in. to 2 in. thick, from scantlings or offcuts. Single boards can be made up from strips of various widths, provided that the thicknesses are uniform. Boards 80 x 40 x 1 in. have been made from strips 2 in. wide in 5 min. Production rate varies with the moisture content of the wood and the type of glue. The edge-gluing machine consists of a pneumatically operated press, supplied with power through a matching unit from a 5 kw. R.F. generator. A simple glue-spreader and an electrically-driven air compressor and reservoir are included in the plant. Two operators are needed. One feeds strips into the glue-spreader and stacks the completed panels as they are ejected from the press; the other

takes the glued strips from the spreader and assembles them on the feed table. (For. Prod. Util. Abs.)

GOOD GLUE JOINTS DIRECT FROM THE STRAIGHT LINE RIPPER

Southern Lumberman, U.S.A, Vol. 183 No. 2286, 1 July 1951, pp. 41-2, 1 illus.

Good glue joints can be made direct from the ripper with a substantial saving in timber, time and labour, and with no loss of joint quality, provided the right saw blades are used and maintained in good condition. The modern machine is described with notes on pressure adjustments, feed speed, safety devices and lubrication. For making glue joints, the over-cutting type is preferred.

The smoothness of the cut depends primarily upon the type and condition of the saw, and recommendations are given for suitable tooth settings, gullets, sizes, swaging, operating speeds, etc. Most rippers are provided with a combination jointing and side-dressing device to keep the saw accurate. Carbide-tipped saws give a longer working life between sharpenings and cut clean and fast, but require careful handling and special grinding. (Tech. Bul. F.D.C.)

PILOT PLANT TEST OF DIELECTRIC HEATING FOR THE EDGE GLUING OF CASE ENDS

N. C. Edwards, L. N. Clarke and R. S. T. Kingston, Forest Products Research Laboratory, Australia, August 1950, 11 pp, illus.

A simple machine has been built for the continuous production of packing case ends using narrow boards which are edge-glued at the rate of 6 ends per minute using R.F. heating. A power output of 400 watts is used. Improvements made as a result of tests on the process include the use of red fibre backing to reduce heat losses from the electrodes and a reduction in length of the upper electrode from 2 ft 6-1/2 in to 1 ft. Urea formaldehyde glue is used, the approximate consumption being 1 lb. of glue per 23 sq ft of joint area. The arrangement of the electrodes and the feed mechanism is described in detail.

An estimate of the cost of case ends produced by this method shows that they compare favourably in this respect with those made on a specially installed Lindermann jointer. Further advantages of the R.F. method are reduced setting times and elimination of subsequent machining. (Tech. Bul. F.D.C.)

ELECTROTHERMAL RUBBER SHEETING

Electrothermal Engineering Ltd, London

A convenient means of applying heat for setting glue lines, particularly in curved panels, is rubber sheeting which incorporates heating elements. This is supplied in a range of sizes and with three alternative loadings of 150, 250 or 450 watts per sq ft.

When used for glue-setting the sheeting is usually jigged in position and left as a fixture to which the product is clamped during the setting process. It can provide a uniform temperature over a large area. If there is a possibility of glue adhering to the sheeting it should be given a protective coating, e.g, of metal foil. Electrothermal rubber sheeting is suitable for use in bag moulding, pressing panel shapes and veneering. It will withstand pressures of up to 200 lb per sq in and accurate temperature controls can be provided. It is claimed that the sheeting has a considerable life, does not harden or become brittle in use, provides uniform heating and is not damaged if the edges are allowed to overhang the panels being glued. (Tech. Bul. F.D.C.)

WOODWORKING EQUIPMENT AND METHODS

(Research in ripsawing.) Rep. For. Prod. Res. Bd., Lond. 1949, 1951 (26 + 2 photos).

A special technique has been evolved for recording by high-speed photography the distribution and movement of sawdust in and around the gullets of saws while they are cutting. Photographs are given showing the distribution of sawdust in the gullets of a 26-in.-diameter circular saw, with 54 teeth, 20° hook and a rim speed of 10,000 ft./min., cutting English Oak at 12% moisture content. (For. Prod. Util. Abs.)

Thunell, B., and Forsberg, P. Undersökningar över sågning med stukade och skränkta ramsågblad. (Researches on sawing with swage-set and spring-set frame-saw blades.) Medd. svenska TräforsknInst. (Träteckn. Avd.) No. 23B, 1951. pp. 14 + (16) + 15 dgms. and gphs. (Sw. sw.) P.R.

The results of tests using swage- and spring-set blades are given in graphs and tables. The following conclusions are drawn: (1) There is no difference in power consumption between the two types. (2) The swage-set blade heats less. (3) The kerf of a swage-set blade will show a narrowing of 0.1 mm. with two regrindings, in the course of sawing 1,000

pieces in 6-1/2 hours. (4) A swage-set blade gives about 9.5% more sawdust than a spring-set blade with the same kerf. (5) There is no difference in output between spring-set and chromium-plated swage-set blades. Unplated swage-set blades have a rather smaller output. (6) There was a considerable variation in dimensions, both in breadth and thickness. The mean deviation from the mean value was about 0.7 mm. for both blades. (7) No difference was found between the depth of profile from the two blades. (8) Sawing butt-end foremost is less satisfactory with a swage-set blade. (For. Prod. Util. Abs.)

Hordern, R. H. The practical application of cutting angles. Wood 16 (9), 1951 (356-8).

Discusses the different methods of treatment for woods with figured grain, for mild soft timbers which saw and plane easily and for Lignum Vitae, the limitations on change in cutter angle imposed by the shape of the cutter head, and the special problems in manufacturing mouldings and stock of curved or irregular section. (For. Prod. Util. Abs.)

Hyler, J. E. Special router work. Sth. Lumberm. 183 (2295), 1951 (62-4).

Discusses the equipment needed where routers are used for special purposes, e.g. production of twist-turned articles, patching, and cutting grooves in plywood edges to prepare them for reception of metal edge strip. (For. Prod. Util. Abs.)

Tompkins, J. Utilizing short lengths. Wood, Chicago 56 (11), 1951 (43, 69). P.R.

Describes a new kind of glue joint, the 'finger joint' used in the manufacture of doors, which is cut by means of a special cutter-head, and makes it possible to use short lengths of wood. (For. Prod. Util. Abs.)

CLOSE-COUPLED ROUGH MILL INSTALLATION

Kaufman Furniture Ltd, Canadian Woodworker, Canada, Vol. 51 No. 7, July 1951, pp. 32, 56

A new layout has been introduced by this company to improve the efficiency and output of individual workmen and hence cut labour costs. About6-7,000 ft of board, mainly birch, are cut per day for framing case goods and for chair and table parts and drawer sides and backs.

A destacker takes the timber from a lift in a corner of the dry storage room and places it on an adjacent roller conveyor. This conveyor is within easy reach of the sawyer who operates a hydraulic cut-off saw. The sawn pieces are carried by live rolls through an undercut planer, thence by belt conveyor through a single surfacer. Here the third man of the team sorts the lengths and piles them on trucks for transport to the appropriate department.

This close-coupled line is 40 ft long, about 1/2 - 1/3 the length formerly required for the same set of operations. Three operators instead of five give the same or a slightly higher, potential production and, since manual labour has been reduced, each man can give his work more attention.

It is emphasised that such a system is suitable for the medium as well as for the larger sized plant. (Tech. Bul. F.D.C.)

Woodworkers' Tool Works designs pyramid joint. Wood-Worker, Indianap. 70 (7), 1951 (70). P.R.

An illustrated description of a new joint developed by the Woodworkers' Tool Works, Chicago. This (Knourek system) joint makes it possible to build up short pieces into strong, durable boards which can be used in furniture. The sectional view of the joint is that of a sloping crenellated wall. A machine for cutting pyramid joint is being designed. (For. Prod. Util. Abs.)

HOLLOW CHISEL MORTISING ATTACHMENTS FOR PORTABLE ELECTRIC DRILLS

E. R. Cole Ltd, Wolf Electric Tools Ltd

For cutting mortises a hollow square chisel is clamped to the end of the heavy duty drill and a mortise drilling bit is inserted in the chuck. The drill is mounted in a small bench stand so that it can be raised or lowered by hand levers. With these appliances mortises can be cut to a depth of 4-1/2 in. The chisels are available in sizes from 1/4 in to 1/2 in. With the Wolf model, a mortise chisel sharpening tool is supplied for each size. (Tech. Bul. F.D.C.)

COMPARATIVE STUDY OF CIRCULAR SAWBLADES WITH SWAGE-SET AND SPRING-SET TEETH

G. G. Klem and O. Karlsen, The Norwegian Institute of Woodworking and Wood Technology, July 1951, 19 pp. (In Norwegian with English summary)

Tests have been made to compare the performance of swage-set and spring-set circular sawblades with regard to power consumption,

thickness of saw kerf, accuracy of timber thickness, characteristics of the sawdust and appearance of the sawn faces. Details are given of the blades and the timber used and the working conditions are described. Tables show the results obtained.

It was found that in most gauges the swage-set blades require slightly more power than the spring-set except at high feed speeds (about 150 ft per min) when they require less. The differences in consumption are slight, however, and of no practical significance. Averaging for all gauges the swage-set blades cut more accurately than the spring-set, the effect being most noticeable in the finer gauges. Feed speed does not affect accuracy when the heavier gauges of saw are used. It was also found that large widths are sawn less accurately than small with both types of blade.

Sawdust produced by swage-set teeth tends to have a rectangular shape while that made by spring-set teeth is made up of thinner, longer pieces. No difference could be observed in the faces of timber sawn with the different blades. (Tech. Bul. F.D.C.)

SELECTION AND APPLICATION OF CUTTERHEADS FOR WOOD

K. W. Duff, Paper to the Wood Industries Section of the American Society of Mechanical Engineers, Wood Working Digest, U.S.A, Vol. 53 No. 9, September 1951, pp. 51-7, 60, 62, 64, 66-71, 12 illus.

The selection of a cutterhead is determined by the quality of finish required, the species and condition of the wood, the machines available and the quantity to be run. Cutterheads are generally chosen to hold knives at the maximum cutting angle found necessary for the various woods machined by the particular user. Smaller angles are then obtained as required by back-bevelling. Even within a given species of wood the most suitable cutting angle varies with the moisture content, increasing as moisture content increases. As the cutter angle is reduced more power is required and a lower limit is thus set by the power available and by the ability of the spindle to transmit this power. Heads are generally built to run at one speed alone but some new machines are equipped with adjustable speeds.

Cutterheads of the straight-knife, milled-to-pattern and circular-bit types are described together with the applications for which each is most suited. Standardization is thought to be required for the size and shape of profile arbors and side spindles and for the sizes of cutterheads. Types of cutterhead fastening described include the set-screw, clamp collar, split cone, and tapered spindle. Suitable materials for heads and knives are reviewed.

Poor cutting generally results in one or more of the following defects: raised grain, fuzzy grain, chip marks, torn grain and knife marks. These defects are defined and methods of prevention are suggested. In particular the effect of jointing is considered and it is suggested that where jointing is carried out the head should be turned at full speed and under a cutting load.

Cutters dull rapidly if they are made of a grade of steel not suited to the work being carried out. (Tech. Bul. F.D.C.)

WOOD FINISHING

WHY COLOR CHANGES IN FINISHED FURNITURE

G. B. Gibson, Industrial Finishing, U.S.A, Vol. 27 No. 11, September 1951, pp. 74-6, 78, 80, 82, 84, 86, 88, 90

The need for uniform colour, together with minimum change with age, is of considerable importance where furniture has a light type of finish, since the furniture may be stored or displayed under varying conditions of sunlight. Also, questions of matching and finish repair may arise.

Light is a frequent cause of colour change, whether darkening or bleaching, and in some cases such as that of linseed oil, alternate yellowing and bleaching occur in the dark and in sunlight respectively. On the other hand the bleaching of organic dyes by light is irreversible.

The author points out that wood itself is photosensitive, usually darkening towards a grey or greyish-brown tint. This can be demonstrated by exposing a panel having a shielded area, to strong sunlight or to ultra-violet light. Moreover, bleached woods tend to revert to their original colour if left for a time without finishing.

The effect on colour change, of the various materials used in the successive stages of finishing, is fully considered, and a simple scheme of experiments is described, by which the influence of the different factors can be assessed.

It is pointed out in conclusion that some change due to age is inevitable but can be much retarded by selection of materials on the lines indicated. (Tech. Bul. F.D.C.)

SPRAY PAINTING WITHOUT A GUN

Product Finishing, Vol. 4 No. 11, November 1951, pp. 62-8, 7 illus.

Electrostatic spraying has recently received much attention in the technical press, and in this article, a description is given of a system developed by the Ransburg Electro-Coating Corp, U.S.A. The liquid to be sprayed is fed from a tank into specially designed conical cups, which rotate in order to distribute the liquid over the interior surface and eject it from the rim of the cup.

The cups are electrified to a high potential and the conveyor holding the articles to be sprayed is earthed, as is one terminal of the electricity supply to the cups.

Every advantage is claimed for this system, especially the elimination of overspray-booth and compressed air installations. It is also claimed, that the process can be used to spray non-metallic articles such as wood, glass, rubber, pottery and plastics.

Although the voltage may be as high as 90,000, the amperage is very small, and it is considered that the operator would be exposed to no industrial hazard through electric shock.

Any type of material capable of being sprayed by a spray gun can be used in this process, and no special type of conveyor is required. Impressive figures are given showing the economy of material and time achieved. (Tech. Bul. F.D.C.)

SEASONING AND PRESERVATION

Narayanamurti, D. Note on treated wooden transmission poles in India. Indian For. Bull. No. 140, 1948. pp. 43 + 13 photos, 4 dgms. 7 refs.

An illustrated account, with sections on: species of wood recommended for use as poles; causes of deterioration; quality and defects; preparation of poles for treatment; preservatives; treating processes; erection of poles, extension of life of partly decayed poles, and service data on treated poles. (For. Prod. Util. Abs.)

Liese, W. Über die Eindringung von oligen Schutzmitteln in Fichtenholz. (Penetration of oily wood preservatives into Spruce wood.) Holz Roh- u. Werkstoff 9 (10), 1951 (374-8). 8 refs. (G.g.) P.R.

A review of literature on the poor absorption of oily preservatives by Spruce wood is followed by a description of an experimental investigation. It has been established that this phenomenon is caused by the irreversible closing of the bordered pits of springwood during drying. These pits are always open in summerwood, closed in spring heartwood, and open in spring sapwood. When sapwood is dried, the bordered pits in the springwood close. Hence oils can penetrate into only summerwood of air-dry timber, springwood being hardly entered by oil and the rays completely impenetrable. The author's treatment of air-dry wood with various chemicals and solvents failed to open the closed pits to any appreciable extent. When, however, green wood was treated with ethanol or acetone, the pits were kept open, and the wood could be impregnated throughout (sapling disks of up to 7 cm. diam, and 5 cm. thick, almost without heartwood, were used). It appears that the closing of the pits is prevented by the low surface tension of these liquids. (For. Prod. Util. Abs.)

Preservative treatments for timber in buildings. British Standard Draft Code of Practice, British Standards Institution, London No. CP (B) 1020, 1951. pp. 18. Price 2s. P.R.

Contains sections on: materials, design considerations, work on site, inspection and testing, and maintenance, as well as a table of preservatives and methods of application. (For. Prod. Util. Abs.)

Richards, I. T. Creosoted Douglas Fir plywood pontoons for marine use. Wood Pres. News 29 (11), 1951 (134-6, 144). P.R.

Many pontoons in British Columbia are now being made from pressure-creosoted Douglas Fir plywood, which has proved much more resistant to marine borers than Red Cedar floats. Creosote penetration is complete, the retention per cu. ft. being 24 lb. for salt-water use and 12 lb. for freshwater use. (For. Prod. Util. Abs.)

Suggitt, J. W. The evaluation of fire-retardant paints: types compared by improved test methods. Woodl. Sect. Index Canad. Pulp Pap. Ass. No. 1198 (F-3), 1951. pp. 6.

Laboratory fire-tube and flame-spread tests using 6 types of paint on wood panels, showed that coatings of the best paints (resin phosphate or sulphamate) over 3 coats of oil paint, prevented destruction of the specimen. A table is given showing fire-retardant quality, ease of application, covering power, drying time, type of surface and washability of the different types. (For. Prod. Util. Abs.)

Kastmark, C. F. Avvattning av virke genom centrifugering. (Removing free water from timber by using centrifugal force.) Pap. ja Puu 33 (11), 1951 (346-52). (Sw.e.) P.R.

Samples of Pine and Spruce varying in size from 4 in. x 9 in. x 17 ft. to 5/8 in. x 3 in. x 6 ft. were steamed for 4 hr. and then dried experimentally in a cylinder with an inner diameter of 6.8 m., rotating on an axis perpendicular to the length of the timber, at 38-40° C. The cylinder had two openings, diametrically opposite, for inserting and removing the timber. About 300 charges, covering 1,300 samples, were dried. The samples were weighed before insertion, and were removed and reweighed after 1, 3, 5, 7, 9, and 24 hr. Centrifuging was carried out at 50, 60, 75, 90 and 120 revs./min. After centrifuging, drying was completed in an ordinary kiln. Figures showing the relationship between the speed of revolution and the weight of water per cu. ft., and the moisture gradients in the timber, are given i n graphs. The following results were obtained: (1) The moisture content was roughly uniform for the same dimensions. (2) The moisture was driven out from the wet inner zone early in drying; drying could therefore take place more evenly throughout the whole section, and there was little or no splitting or checking. (3) The yellow colouring was very much less than in kiln-dried timber. (4) The time needed for kiln drying was reduced by about a half. (5) Optimum speeds were 58-60 revs./min. for timber 1 in. thick and over, and 90 revs./min. for timber 5/8 in. thick. (6) Most of the water was removed during the first 4 hr. and it was not found economical to carry out the entire seasoning process by centrifuging. (7) Timber containing a high proportion of heartwood is not suitable for centrifuging, since it contains little free water.

Diagrams are given showing the lay-out of an installation using a centrifuge, and the details of a centrifugal drier. From 1945 to 1947, 5/8- 3/4- 7/8-, and 1-in. sidings were dried commercially in centrifuges. The power consumption was about 12.5 kw per centrifuge charge. Centrifuging was economic only when the wood contained a certain proportion of water (at least 50-55% of its volume). The results obtained were similar to those obtained in the laboratory. (Cf. For. Abstr. 13 (No. 1674) and preceding abstract.) (For. Prod. Util. Abs.)

Diffusion of water vapour through wood (at different degrees of air pressure). Rep. For. Prod. Res. Bd., Lond. 1949, 1951 (12).

Experiments were made using an improved technique, by which the mouth of a 4-oz. bottle

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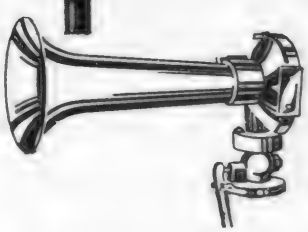

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containing water was covered with a disk of wood, and the top of the bottle was sealed with a Perspex screw top. The assembly was weighed after various periods of exposure to P_2O_5. The diffusion rate for all pressures was greater through Beech than through Oak, and it increased for both species with decreasing air pressure. The diffusion rate in both radial and tangential directions was measured for Beech, Oak, Scots Pine, Spruce and Krabak (Anisoptera sp.). The tangential flow through Beech and Oak was found to be appreciably greater than the radial flow; for the other 3 species the difference was less marked. (For. Prod. Util. Abs.)

WOOD CONSTRUCTION

Directory of building research and development organizations in Europe. United Nations, Geneva 1951. pp. 111. (E.) P.R.

The directory gives addresses, fields of work, names of persons in charge, and some information on the structure, financing, and publications of national organizations in Europe, and 23 international organizations, concerned with building research and development. An introductory article outlines the evolution of building research. A name index and subject index are included. From editors' summary. (For. Prod. Util. Abs.)

Baechler, R. H., and Richards, C. A. Deterioration of wood in cooling towers. Trans. Amer. Soc. mech. Engrs. 73 (8), 1951 (1055-9). 7 refs. P.R.

The significant properties of Redwood (Sequoia), the types of deterioration to which it is subject, and the conditions prevailing in cooling towers are reviewed. Pieces of slats removed from 12 towers after 6-8 years of service, and exposed to 5 fungi in laboratory tests, showed much greater (weight) loss in decay than pieces of unused Redwood. Thin cross-sections exposed to solutions of Na_2CO_3 and N_aC1O were less resistant to decay than those exposed to water. Authors' conclusion. (For. Prod. Util. Abs.)

Money, P. L. Timber for coast defences Quart. Rev. Timb. Developm. Ass. 3 (3), 1951 (15-6).

A brief analysis of 50 answers to a questionnaire on the timbers in Great Britain used for walings, piles and land ties, dimensions required, life in service and performance of each timber, preservatives used and their effectiveness, and incidence of Teredo and Limnoria. (For. Prod. Util. Abs.)

UTILIZATION OF LOW GRADES AND WASTE

METHODS OF TEST FOR WOOD CHIP BOARDS, WOOD WASTE BOARDS AND SIMILAR BOARDS

British Standards Institution, BS 1811:1952, 16 pp, 2s

The Standard covers boards consisting of particles of wood waste bonded with synthetic resin and/or other organic binder. Recommendations are made for the selection, preparation and conditioning of test pieces. Methods of test are specified for flexural strength; deflection and effective modulus of elasticity; deflection under sustained load; resistance to impact; density and variation in thickness; volatile content including moisture; water absorption; dimensional and weight changes caused by moisture; thermal conductivity; surface spread of flame. Apparatus and test arrangements suitable for some of the tests are shown diagrammatically. (Tech. Bul. F. D. C.)

Ellwanger, R. Suspension burning of bark refuse. Tappi 35, no. 3:108-11 (March, 1952).

Previously classified as a waste product resulting from the operation of paper mills, bark refuse now assumes a prominent place as a low-cost substitute fuel for steam and power generation. A short history of wood burning is presented, from piles to the development of a boiler, furnace, and auxiliaries, which are designed primarily for suspension burning and utilize flash drying and extreme furnace turbulence. Fuel handling and preparation and fuel burning and the combustion system (including an analysis of fly-ash reinjection) are discussed to illustrate the problems encountered in the efficient burning of this material. Data are included on predicted and actual performance, together with efficiencies and carbon loss. 2 tables and 4 figures. E.S. (Bul. Inst. Paper Chem.)

Kuhn, W. H., Carsey, E. A., and Gusler, D. L. Power from wood waste. Mech. Eng. 73, no. 10:809-11 (October, 1951).

The powerhouse of a modern furniture factory is described which was designed to operate on wood waste as a primary fuel with coal as a standby fuel. Details of the sawdust-, chips-, and shavings-collecting system, storage bin, drag-type conveyors, and the two water-tube boilers with suspension burning are given. Since the factory operates on an eight-hour day with load variations from 150 to 1500 kw., two multicylinder uniflow engines directly connected

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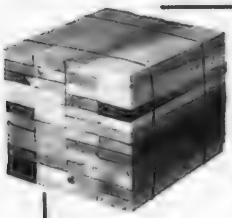

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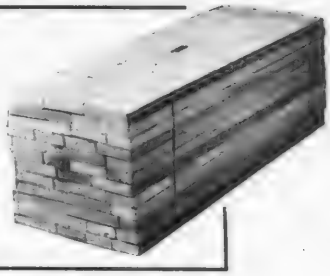

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to two 1250-kv.-amp. generators were selected for power generation. The results of the installation have been gratifying; it is possible to produce 6.7 lb. of steam for every pound of wood waste. 7 figures. E.S. (Bul. Inst. Paper Chem.)

PULP AND PULP PRODUCTS

Wood pulp and pulpwood statistics. Fibre Contain. 36 (8), 1951 (130, 132-8). P.R.

Presents, in tables and charts: (1) data on pulpwood receipts, consumption and inventories, in the U.S.A. over the period 1939-50; (2) cords of wood per ton of pulp, by regions, in 1947, and by pulp grades in 1929, 1939, and 1947; (3) value of wood per cord by species (1939 and 1947) and by years (since 1899); (4) quantities of pulpwood species used (1929, 1939, and 1947); (5) species used in different pulp grades (1947), and data on wood pulp. (For. Prod. Util. Abs.)

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Sawmills, Dry Kilns, Treating Plant, Guayaquil—Ecuador, S. A.

Fickler, Hans-Heinrich. The status of development of testing specifications for the properties of wood fiberboard. Svensk Papperstidn. 55, no. 5:153-72 (March 15, 1952). (In German; English and Swedish summaries)

This is an extensive review of the testing methods developed in different countries of the world for the evaluation of the properties of wood fiberboards for the purpose of an eventual international standardization. The procedures have been arranged and are discussed under the subdivisions physical (specific gravity and thickness; moisture and conditioning; water absorption, swelling, and linear expansion; heat conductivity; acoustical insulating properties; and water permeability), elastic and strength (modulus of elasticity; tensile strength in the direction of the board and perpendicular to it; crushing and breaking strength; bending strength; compressibility; impact bending strength; and hardness), and performance methods (nail-holding power; resistance to nail penetration; wear; resistance to fire, insects, fungi, and chemicals; and accelerated aging). Different methods for examining one specific property are classified under one heading. The first step to co-ordinate the scattered efforts in this field on an international basis was taken in 1947 by the Food and Agriculture Organization of the United Nations. Under its auspices international conferences were held in Washington, Geneva, and Igls (Austria), with J. Markwardt as chairman of the subcommittee in charge of the field work. Finally, an international agreement on a considerable number of testing methods was reached at the last conference in Igls in 1951. A list of U. S., Scandinavian (Swedish, Norwegian, and Finnish), German and Austrian, English, and French standards is appended. 2 tables, 7 figures, and 13 references. E.S. (Bul. Inst. Paper Chem.)

CHEMICAL UTILIZATION

Gralen, N., and Berg, S. Treatment of wood with ultrasonic waves. Journal of Polymer Science, Easton, Pa. 6 (4), 1951 (503-7). 12 refs. (E.f.g.) D.S.I.R.

Presents the results of a 1942-43 investigation on acetone-extracted Spruce wood powder treated with ultrasonic waves. It has been found that these cause a destruction of the biological structure of wood and split the bonds between lignin and cellulose or other carbohydrates. After treatment with ultrasonics, ca. 50% of the wood can be dissolved in $CuO\text{-}NH_3$ solution. The dissolved carbohydrate material consists of two main components with two different sedimentation rates. These components have been tentatively referred to as cellulose and hemicellulose. (For. Prod. Util. Abs.)

Algar, W. H., and Giertz, H. W. Fiber structure and pulp properties. II. The influence of ultrasonic treatment on wood cellulose fibers. Svensk PappTidn. 54 (20), 1951 (693-700). 8 refs. (E.sw.g.) P.R.

(Cf. For. Abstr. 13 (No. 776).) Ultrasonic treatments were applied to 3 holocellulose preparations, 3 semichemical acid sulphite pulps, 1 paper- and 3 rayon-type sulphite pulps, an overcooked sulphite and a sulphate pulp, all prepared from the same sample of Picea abies. Results are illustrated by 22 photomicrographs. Fibres generally, especially those with a high hemicellulose content, swelled to more than their water-swollen condition as a result of ultrasonic treatment. In some cases "balloon" formation occurred as in swelling by chemical agents. Fibres of the rayon and overcooked pulps swelled considerably in spite of their low hemicellulose content, because the primary wall, which generally acts as a restraint on swelling, had been largely destroyed by strong chemical action. The sulphate fibres swelled comparatively little in spite of a fairly high hemicellulose content, probably because bonds restraining swelling had been formed during chemical treatment. (For. Prod. Util. Abs.)

Risi, J. Plastics and chemicals from wood sugars. Pulp Paper Mag. Can. 53, no. 2:63-4, 70 (February, 1952).

The production cost of ethyl alcohol from spent sulfite liquor does not compare favorably with production costs from other sources. However, if the alcohol is converted to ethylene, valuable derivatives, such as acetaldehyde, butadiene, allyl alcohol, vinyl chloride, vinylidene chloride, and chlorinated ethylene compounds can be prepared. These are widely used in the preparation of various synthetic substances, and the versatile procedure which could be employed would be able to meet the periodic variations of market conditions. Another important means of using lignocellulosic waste materials is found in the preparation of fumaric acid and its derivatives. Fumaric acid is an important raw material for a wide variety of resins, and maleic anhydride, to which it is easily converted, is used in the manufacture of varnishes. Glucose from agricultural and wood wastes can be used as the starting material and the industrial preparation is a relatively simple fermentation process. 1 table. M. W. (Bul. Inst. Paper Chem.)

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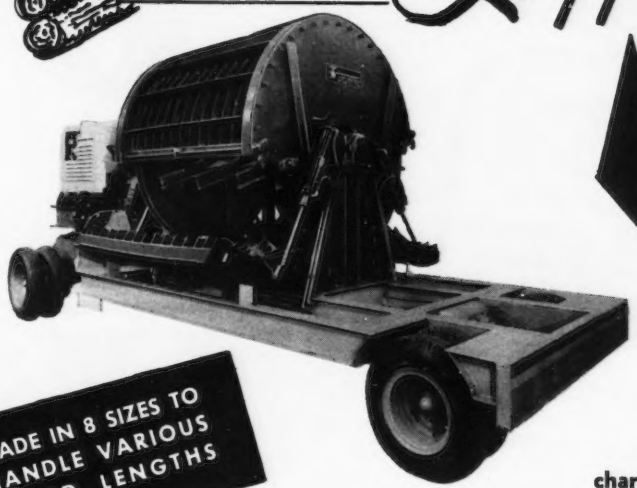

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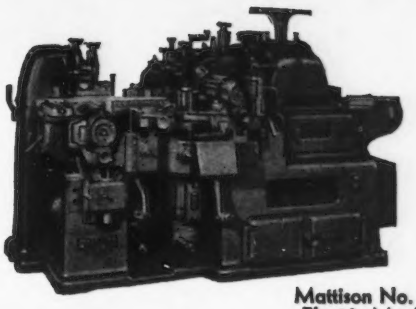

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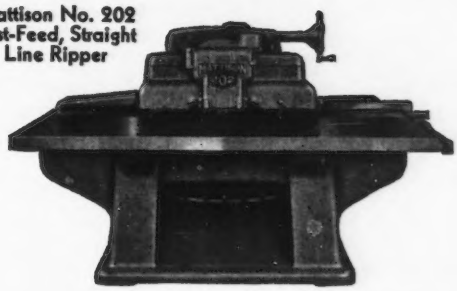

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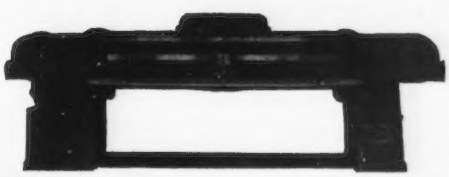

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